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POWER SUPPLY

Model CK 60–0.5 (M)

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Serial No. H-42506

INSTRUCTION MANUAL

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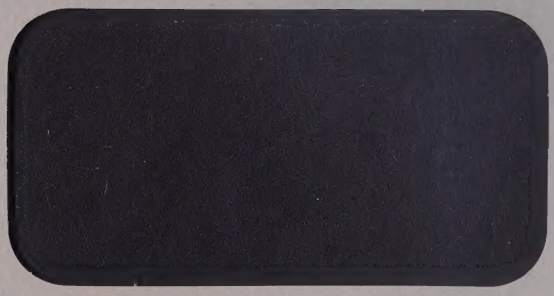

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CK

REGULATED DC SUPPLY

design group

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The KEPCO equipment described in this instruction manual is of proprietary design, covered by one or more of the following United States patents and/or by other (U.S. and Foreign) Patents or patents pending.

2,992,379	3,112,439	3,241,042	3,275,948
2,992,386	3,128,423	3,243,690	3,303,411
3,028,538	3,131,344	3,243,749	3,303,412
3,056,905	3,210,619	3,275,925	3,303,415
3,088,053	3,226,628	3,275,927	3,305,763
3,092,757	3,241,054		

Canadian Patents: 733629 – 736084
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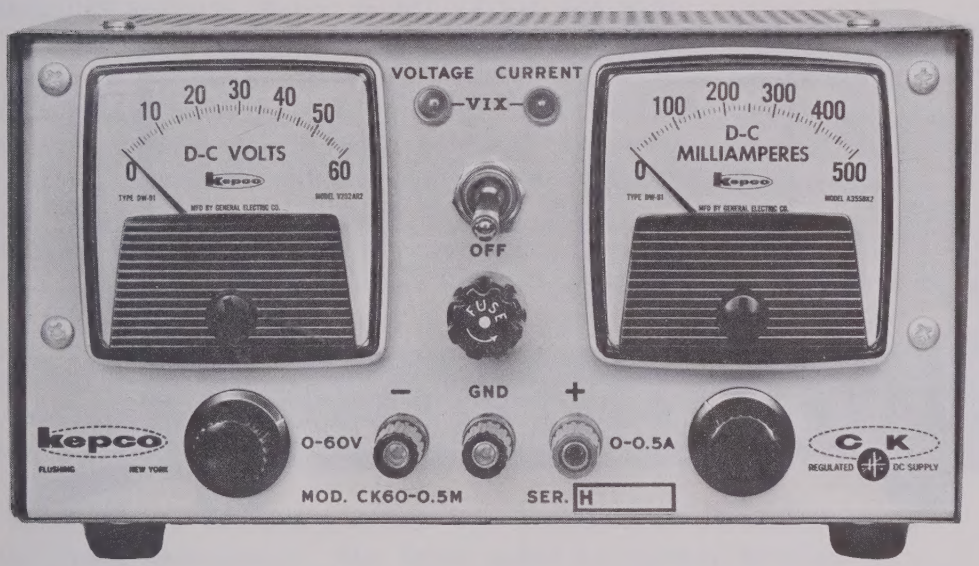


FIG. 1-1 CK POWER SUPPLY TYPICAL FRONT VIEW

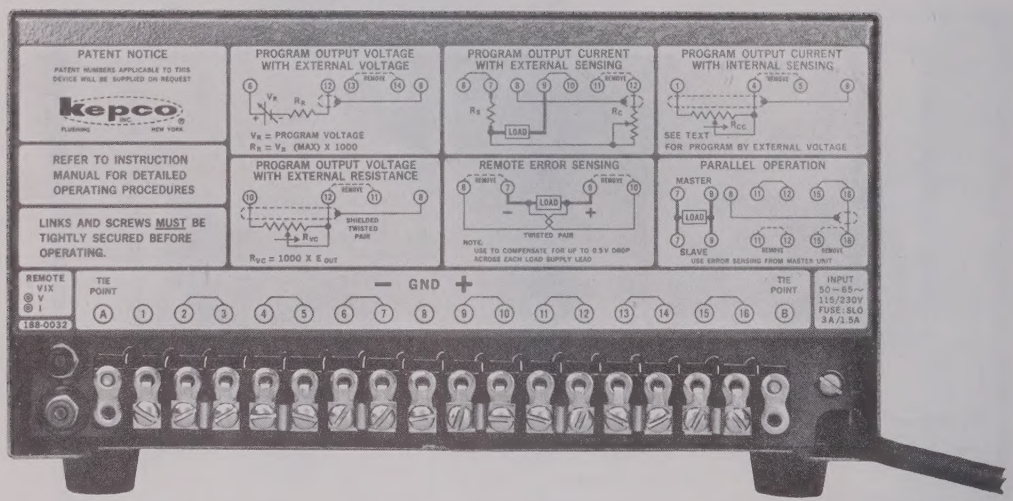


FIG. 1-2 CK POWER SUPPLY TYPICAL REAR VIEW

SECTION I - INTRODUCTION

1-1 SCOPE OF MANUAL

1-2 This instruction manual contains information for the installation, operation, and maintenance of the KEPCO Series CK regulated power supplies.

1-3 GENERAL DESCRIPTION (Refer to FIG.'S 1-1 and 1-2)

1-4 The Kepco CK design group consists of a series of precision regulated Power Supplies whose specifications, electrical characteristics and mechanical outline dimensions are identical except as noted in Table 1-1. Multi-turn, precision potentiometers allow continuous adjustment of either output voltage or output current from the front panel. Automatic crossover between constant voltage and constant current mode of operation is provided with front panel "VIX" light indication of the operating mode. The rear barrier strip serves for the convenient access to the circuitry for the purpose of remote programming or system integration. Built-in forced air cooling with lateral circulation provides adequate ventilation for continuous operation at any output within the specified range.

1-5 The Power Supply chassis and case are constructed of plated, cold-rolled steel throughout. The front panel is etched, brushed aluminum with a protective coating.

1-6 The amplifier of the Power Supply, containing the major part of the circuit components is designed on a plug-in type printed circuit board and may be conveniently disassembled for maintenance purposes. All other components are also easily accessible due to open frame construction of the main chassis.

1-7 SPECIFICATIONS, GENERAL

a) Input Requirements: 105V AC to 125V AC or 210V AC to 250V AC — 50 H_Z to 65 H_Z single phase

(For maximum input current see Table 1-1.)

b) Ambient Operating Temperature: -20°C to +50°C.

c) Storage Temperature: -40°C to +85°C.

d) Isolation Voltage: Maximum output voltage plus 500V DC between chassis and either output terminal.

1-8 SPECIFICATIONS, GENERAL PERFORMANCE

a) Controls: Continuously adjustable 10-turn voltage and current controls permit output settings from zero to the maximum voltage and current. Resolution: 0.05% of maximum output.

b) Programming: Special terminals provide for remote resistive programming of voltage or current at 1000 ohms per volt. Programming terminals are also provided for programming by means of remotely located voltage or current signals.

c) Automatic Crossover: The automatic crossover circuit switches the operating mode of the power supply automatically from constant voltage to constant current or vice versa depending on the load relationship to the panel voltage and current adjustments. In the voltage regulation mode, the current control serves as a current limit adjustment while in current regulating mode, the voltage control serves as a voltage limiting adjustment.

d) VIX Indicators: The power supply's operating mode is indicated by a pair of front panel signal lamps. One lamp is lighted during voltage regulated operation, the other during current regulated operation (internal current sensing only). Crossover from one mode to the other is signalled by the extinction of one lamp and the lighting of the other.

e) VIX Remote Signal: A pair of rear-panel pin jacks, labelled "V" and "I" provide external access to the VIX signal. Pin V is 8 volts positive with respect to pin I during voltage regulated operation. Pin I is 8 volts positive with respect to pin V during current regulated operation. Maximum loading: 10 K ohms; isolated from ground and the output terminals of the power supply. Crossover from one mode to the other is signalled by an abrupt polarity reversal.

f) Remote Error Sensing: Error sensing terminals enable specified voltage regulation to be maintained directly at the load by compensating for voltage drops up to 0.5 volts across each load supply lead.

g) Series/Parallel Operation: Automatic crossover capability permits series or parallel operation in either voltage or current regulating modes. Units operate automatically to share a load by means of their automatic crossover feature. Connections are also provided for operation in master/slave configuration.

h) Cooling: Lateral circulation by blowers insures efficient heat transfer.

i) No Voltage Overshoot: No output voltage overshoot from turn-on, turn-off or power failure for output settings above 25% of maximum rated voltage. Below 25%, output overshoot is a function of load and is negligible for loads in excess of 10%.

1-9 SPECIFICATIONS, VOLTAGE REGULATION MODE

a) Regulation:

1) Line: Less than .005% output voltage change for 105-125V AC or 210-250V AC line variation, at any output voltage within the specified range.

2) Load: Less than 0.01% or 0.5 mV output voltage change, whichever is greater, for no load to full load change at any output voltage within the specified range. The 0.5 mV specification governs throughout the entire range of the model CK 2-8M.

b) Stability: Output voltage varies less than 0.01% or 2 mV, whichever is greater, over a period of 8 hours after warmup. Measured at constant line voltage, load and ambient temperature.

c) Temperature Coefficient: Output voltage changes less than 0.01% per °C.

d) Ripple: Less than 0.5 mV rms.

e) Recovery Time: 50 microseconds.

f) Output Impedance: Specified for each model within the load frequency range shown in Table 1-1. Above 10 kc include the reactive impedance of the effective series inductance as indicated.

1-10 SPECIFICATIONS, CURRENT REGULATION MODE

a) Output Range:

1) Internal Sensing: Current regulation from less than 0.2% to 100% of the maximum specified current. Automatic crossover to voltage limiting provided.

2) External Sensing: Current regulation from 1 mA to 100% of the maximum rated current.

b) Compliance:

1) Internal Sensing: Voltage compliance range is zero to the voltage control setting. The setting is adjustable, zero to 100% of the rated voltage range.

2) External Sensing: Voltage compliance is zero to 100% of the maximum output voltage.
For any selected current value, the output voltage is automatically varied throughout the compliance range as required to regulate the output current through a variable load.

c) Regulation, Internal Sensing:

1) Line: Less than 0.01% or 0.2 mA, whichever is greater, output current change for 105-125V AC or 210-250V AC line variation at any output current within the specified range. For models rated at 2 amperes or less output current, the 0.2 mA regulation specification governs.

2) Load: Less than 0.01% or 0.2 mA, whichever is greater, output current change for the maximum change in load resistance within the rated compliance range. For models rated at 2 amperes or less output current, the 0.2 mA regulation specifications governs.

d) Regulation, External Sensing:

1) Line: For 105-125V AC or 210-250V AC line variations, output current changes less than 0.01% when the specified voltage sample is maintained across the external sensing resistor.

2) Load: For the maximum change in load resistance, within the rated compliance range, output current changes less than 0.01% when the specified voltage sample is maintained across the external sensing resistor.

3) The sensing resistor is chosen to produce a one volt drop at the maximum operating current. A separate control is used externally to provide high resolution current adjustability.

e) Stability: Output current varies less than 0.05% or 1 mA, whichever is greater, over a period of 8 hours after warmup. Measured at constant line voltage, load and ambient temperature.

f) Temperature Coefficient: Output current changes less than 0.05% (of maximum output current) per °C.

g) Ripple: Less than 0.05% of output current setting or 0.01% of maximum current rating, whichever is greater, rms.

1-11 SPECIFICATIONS, PHYSICAL

a) Meters: Model numbers in Table 1-1 include 2 1/2", rectangular voltmeter and ammeter; 2% full scale accuracy. Unmetered units have the suffix "M" deleted from the model number.

b) Terminals and Controls:

1) On Front Panel: AC on-off switch, fuse, and two VIX mode lamps. 10-turn voltage control, 10-turn current control, DC output and ground terminals. ("Five Way" binding posts)

2) On Rear of Chassis: Two VIX remote signal 0.08" pin jacks. Barrier strip connections for: remote error sensing, voltage and current programming by remote resistance and/or voltage, master-slave, parallel operation, external current sensing. DC output and ground terminals. Output terminals are isolated from the chassis, either positive or negative terminal may be grounded.

c) Dimensions: 4 1/4" H x 8 5/32 W x 13" D (behind rack-adapter), 13 5/8" overall.

d) Finish: Panel, etched alumimum, brushed and coated.
Case, gray hammertone.

1-12 ACCESSORIES

1-13 Accessory equipment for this power supply is available (but not supplied) to increase its range of applications.

a) VIX-1 RELAY, translates the VIX remote signal, available at two connectors in the rear of the unit, into a heavy duty relay closure for external signal applications.

b) KP-10 PROGRAMMING PANEL, precision decade programming resistors for 6 digit voltage programming and 3 digit current programming.

c) FG-100, FUNCTION GENERATOR, precision, slow speed, triangular wave generator for voltage programming of the power supply.

d) MP 1-3000, MOTORIZED PROGRAMMER, provides a mechanical 10-turn potentiometer sweep.

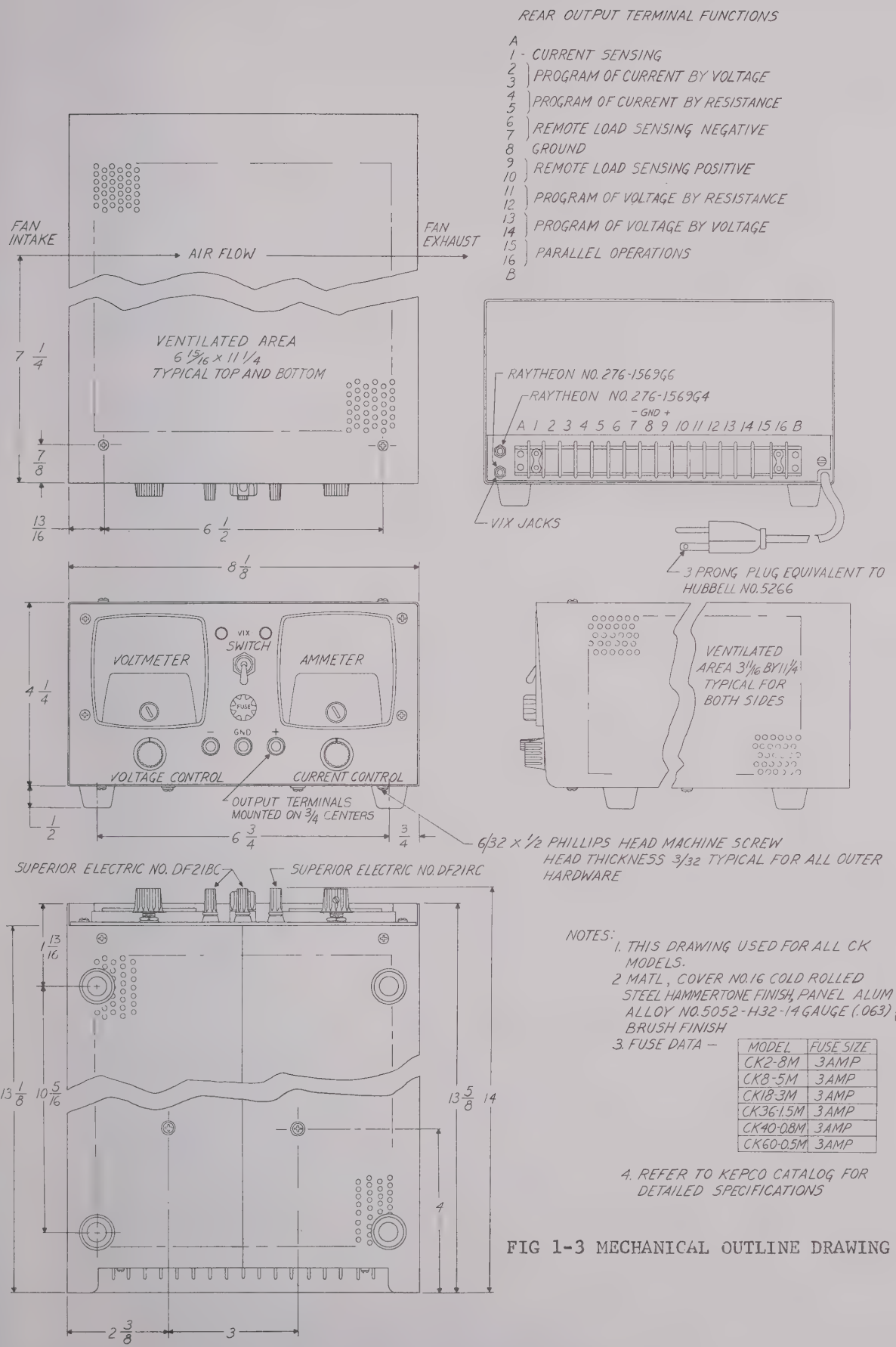
e) VIP-1, OVERVOLTAGE/OVERCURRENT PROTECTOR, a 1% or 0.1V overvoltage will crow-bar the supply within 50 μsec.

f) VIP-3 OVER AND UNDER VOLTAGE OVER AND UNDER CURRENT PROTECTOR

A 1% or 0.1V over or under voltage will crow-bar the supply within 50 μsec.

MODEL	DC OUTPUT RANGE		OUTPUT IMPEDANCE OHMS MAX.			MAX. INPUT AMPS At 125 V AC
	VOLTS	AMPS	DC to 100 CPS	100 CPS to 1 KC	1 KC to 100 KC + μH	
CK 2–8M	0–2	0–8	0.065×10^{-3}	0.01	0.05+0.5	1
CK 8–5M	0–8	0–5	0.16×10^{-3}	0.01	0.05+0.5	1.2
CK 18–3M	0–18	0–3	0.6×10^{-3}	0.01	0.05+0.5	1.3
CK 36–1.5M	0–36	0–1.5	2.4×10^{-3}	0.02	0.08+0.8	1.5
CK 40–0.8M	0–40	0–0.8	5×10^{-3}	0.02	0.08+0.8	1
CK 60–0.5M	0–60	0–0.5	12×10^{-3}	0.02	0.08+0.8	1

TABLE 1-1 SPECIFICATION, KEPCO CK DESIGN GROUP



NOTES:

1. THIS DRAWING USED FOR ALL CK MODELS.
2. MATL, COVER NO.16 COLD ROLLED STEEL HAMMERTONE FINISH, PANEL ALUM ALLOY NO.5052-H32-14 GAUGE (.063) BRUSH FINISH
3. FUSE DATA —

MODEL	FUSE SIZE
CK2-8M	3 AMP
CK8-5M	3 AMP
CK18-3M	3 AMP
CK36-1.5M	3 AMP
CK40-0.8M	3 AMP
CK60-0.5M	3 AMP

4. REFER TO KEPCO CATALOG FOR DETAILED SPECIFICATIONS

FIG 1-3 MECHANICAL OUTLINE DRAWING

SECTION II - INSTALLATION

2-1 UNPACKING AND INSPECTION

2-2 This power supply has been completely tested and inspected at the factory prior to packing and is ready for installation and operation. No special precautions are necessary for unpacking the power supply. Inspect the instrument for obvious shipping damage before attempting to operate it. Perform an operational check as described in Par. 2-13. If there is any indication of damage, file a claim immediately with the transport service responsible.

2-3 TERMINALS AND CONTROLS

2-4 For the location of all terminations and controls, refer to FIG.'S 2-2 and 2-3 as well as Tables 2-1 and 2-2. The nomenclature used will be followed throughout this manual.

2-5 AC INPUT REQUIREMENTS

2-6 This power supply is normally supplied for operation on a single phase, nominal 115V AC line. For conversion to 230V AC line operation, refer to FIG. 2-1. Refer to Table 1-1 for Input Current requirements.

2-7 GROUNDING

a) AC Ground. The power supply is equipped with a 3 wire safety line cord and polarized plug. The third (green) wire in the line cord is connected to the chassis and the case of the unit. If a two terminal receptacle in combination with an adaptor is used, it is imperative that the chassis of the power supply be returned to AC ground with a separate lead.

b) DC Ground. The DC output is isolated from the AC power line and from any direct connection to chassis or ground. The positive side of the output is connected to chassis through a capacitor in series with a resistor. The maximum voltage that can be supported between wither output terminal and ground or chassis is 500V DC plus the maximum output voltage of the power supply. Either side of the output may be grounded. Convenient grounding terminals are provided at the front panel binding post and at the rear terminal strip.

2-8 LOAD CONNECTION

2-9 The load may be connected to the front panel binding posts or at the rear terminals. The regulation specifications as given in Section I are valid for rear terminal connections only. If optimum regulation directly at the load is essential, remote error sensing as described in Par. 3-16 must be applied.

2-10 COOLING

2-11 The power transistors and the rectifier assembly are maintained within the correct operating temperature by a fan circulating air laterally through the power supply. Side-panel openings and the top of the case must be kept clear from obstructions to insure proper circulation.

2-12 If the supply must be rack mounted or installed into confined space, care must be taken that the ambient temperature does not rise above the limit specified in Section I of this manual.

2-13 OPERATIONAL CHECK

2-14 A simple operational check after unpacking and before permanently installing the power supply is advisable. The purpose of the test is to check the power supply for any damage resulting from shipment.
Note: Refer to FIG. 2-2 and FIG. 2-3 for location of front and rear terminations.

a) Connect power supply to 115V AC line. Refer to Paragraph 2-5 for 230 V line operation and to Table 1-1 for input current requirements.

b) Turn "Current Control" fully clockwise. Rotate "Voltage Control" fully counter clockwise and then clockwise for one turn. For units without metering, connect a DC voltmeter across the rear output terminals. The range of the voltmeter must be sufficient to cover the maximum output voltage of the power supply.

c) Turn power "on". Slowly rotate the "Voltage Control" clockwise and observe the gradual increase of the output voltage. The "Voltage" VIX light should be on and the "Current" VIX light should be out. Turn power "off". Turn "Current Control" fully counter clockwise.

d) Connect a short circuit across the output terminals, consisting of a length of heavy copper wire. For unmetered models an ammeter with sufficient range to cover the maximum output current of the power supply may be connected in series with the short circuit.

e) Turn power "on". Rotate the "Current Control" slowly clockwise. A smooth increase in output current should be observed on the output current meter. The "Current" VIX light should be on, and the "Voltage" VIX light should be out. Turn power "off". This completes the operational check of the power supply.

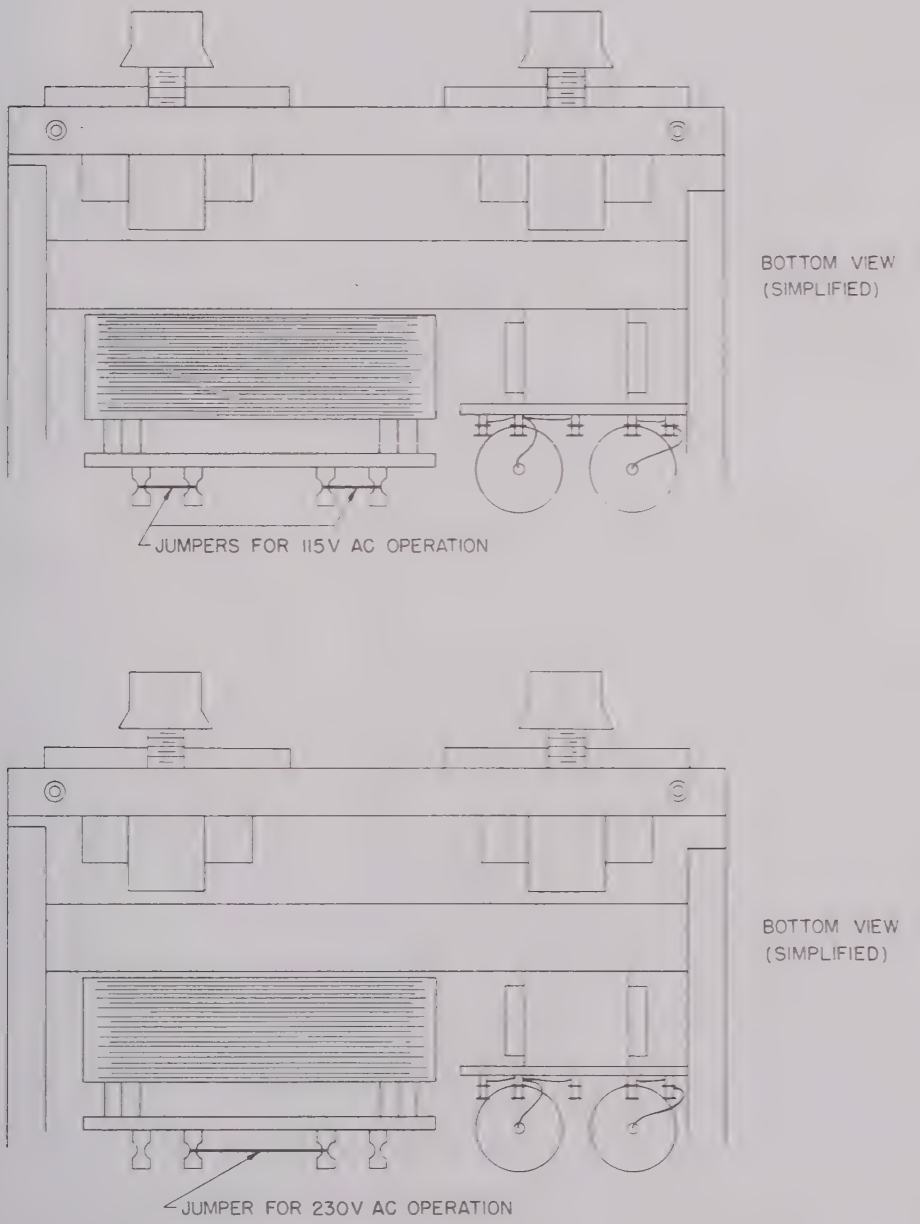


FIG. 2-1 TRANSFORMER CONNECTIONS FOR 115V AC AND 230V AC

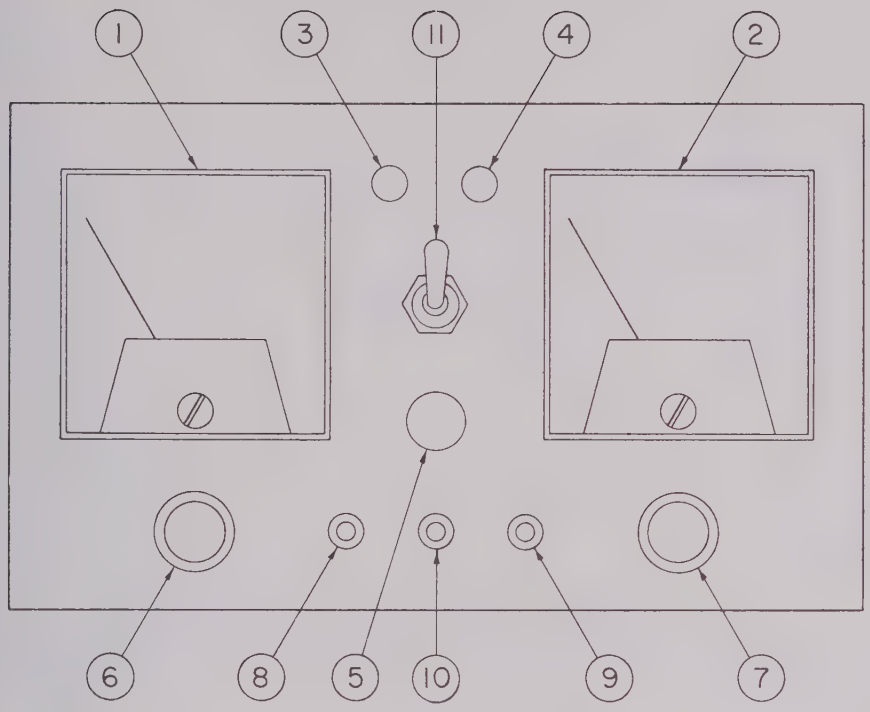


FIG. 2-2 TERMINATIONS, FRONT

TABLE 2-1 TERMINATIONS, FRONT

NO.	TERMINATION OR CONTROL	FUNCTION
1	VOLTMETER	INDICATES OUTPUT VOLTAGE
2	AMPERE METER	INDICATES OUTPUT CURRENT
3	VIX INDICATOR	DISPLAYS VOLTAGE OPERATING MODE
4	VIX INDICATOR	DISPLAYS CURRENT OPERATING MODE
5	FUSE	PROTECTS MAIN TRANSFORMER
6	VOLTAGE CONTROL	TEN TURN POTENTIOMETER, SETS OUTPUT VOLTAGE
7	CURRENT CONTROL	TEN TURN POTENTIOMETER, SETS OUTPUT CURRENT
8	OUTPUT TERMINAL (-)	MINUS TERMINAL, DC OUTPUT
9	OUTPUT TERMINAL (+)	PLUS TERMINAL, DC OUTPUT
10	OUTPUT TERMINAL(GND)	CHASSIS CONNECTION, RETURN TO AC GROUND
11	LINE SWITCH	CONNECTS UNIT TO AND FROM AC POWER LINE

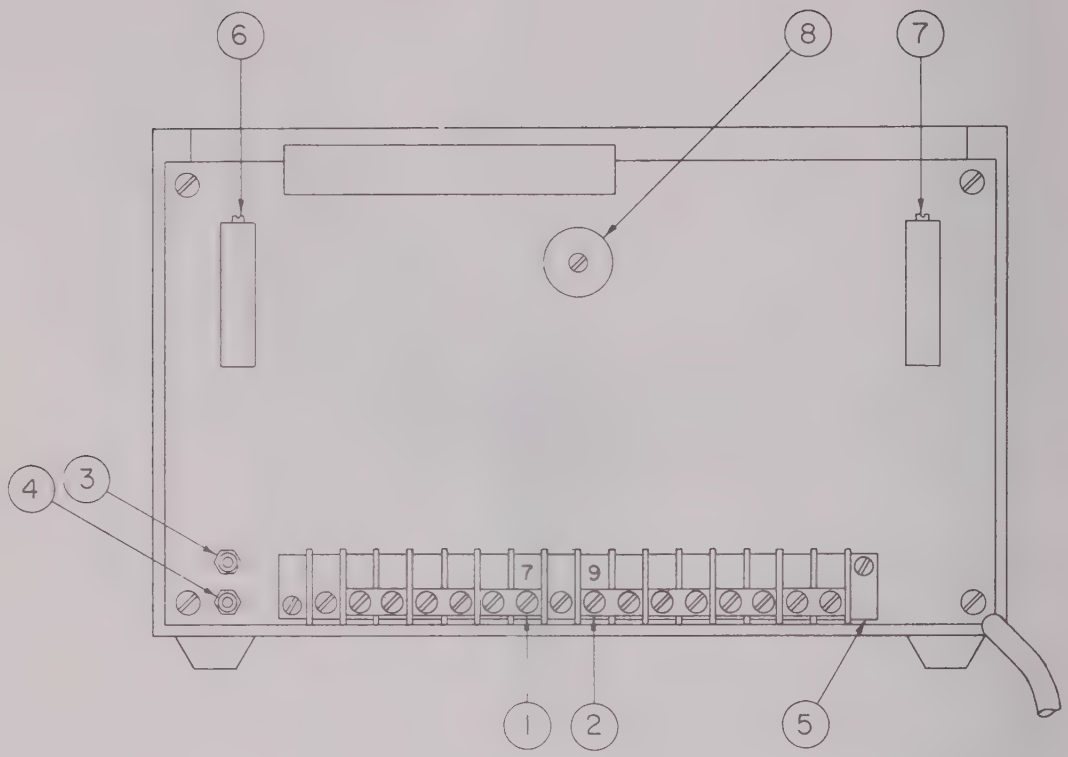


FIG. 2-3 TERMINATIONS, REAR

TABLE 2-2 TERMINATIONS, REAR

NO.	TERMINATION OR CONTROL	FUNCTION
1	OUTPUT TERMINAL (-)	MINUS TERMINAL, DC OUTPUT
2	OUTPUT TERMINAL (+)	PLUS TERMINAL, DC OUTPUT
3	VIX CONNECTOR	VIX SIGNAL OUTPUT (+ IN V MODE, - IN I MODE)
4	VIX CONNECTOR	VIX SIGNAL OUTPUT (- IN V MODE, + IN I MODE)
5	REAR BARRIER STRIP	16 CONNECTIONS TO INTERNAL CIRCUITRY (SEE SEC. 3)
6	R40, POTENTIOMETER	MAXIMUM CURRENT ADJUST (SEE SEC. 5)
7	R42, POTENTIOMETER	MAXIMUM VOLTAGE ADJUST (SEE SEC. 5)
8	R64, POTENTIOMETER	CURRENT COMPENSATION ADJUSTMENT

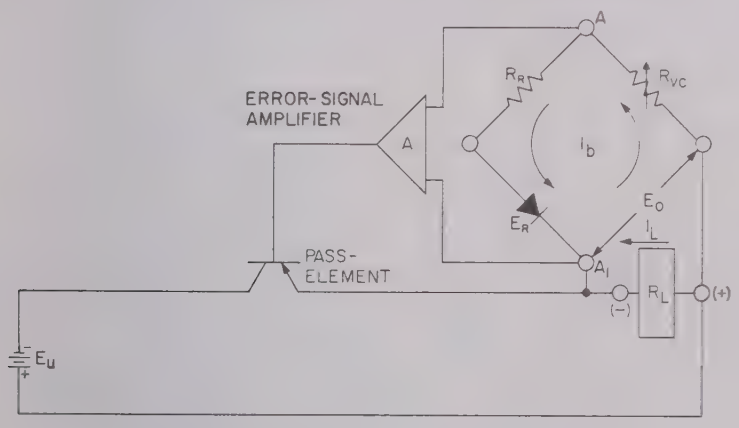
3-1 REMOTE PROGRAMMING OF KEPCO POWER SUPPLIES

3-2 General: In the Kepco Series "CK" Power Supplies, two comparison bridge circuits are used, each of which permit full range programming by resistance, voltage, current or conductance. The versatility of these circuits are so great that only the more common modes of operation can be described in this manual. For a more thorough coverage of power supply applications the "Kepco Power Supply Handbook", available from the Kepco Publication Department, is recommended.

In order to familiarize the user of this equipment with the power supply terminology used in this manual, and with various modes of operations described in the following pages, the basic relationships governing the Kepco Bridge Regulator should be clearly understood and kept in mind.

The bridge consists of four arms with the error amplifier connected to the "null" points (A, A'). (See FIG. 3-1) The error amplifier, the power-source and the pass element constitute an inverting power amplifier which tends to regulate in such a way that equations (1), (2), and (3) are always valid. With these three basic equations in mind, the implications of the circuit variations given in the following paragraphs should become evident.

FIG. 3-1 KEPCO COMPARISON BRIDGE (SIMPLIFIED)



E_u = Unregulated Source
I_L = Load Current
I_b = Bridge Current
E_o = Output Voltage
E_r = Reference Voltage
R_L = Load Resistance
R_{vc} = Voltage Control Resistance
R_r = Reference-Resistance
A = Open Loop Gain Of Error Signal Ampl.

At balance: $E_{AA'} = 0$

(1) $\frac{E_r}{R_r} = \frac{E_o}{R_{vc}}$ (2) $I_b = \frac{E_r}{R_r}$ (3) $E_o = I_b R_{vc}$.

3-3 ADJUSTMENTS FOR EXACT PROGRAMMING RATIO

3-4 Definition. The setting of the "Voltage Control" on the front panel adjusts the output voltage at a fixed, resistance to voltage ratio, which is determined by the bridge-current (I_b) flowing through the voltage control potentiometer (R_{VC}). Referring to our defining equations in Paragraph 3-2, and combining equations (1) and (2), we have: $E_O = I_b R_{VC}$ (equation 3). If therefore the bridge current is equal to 1 mA (as in all CK power supplies) we need, by Ohm's Law, 1000 ohms of control resistance (R_{VC}) for every volt of output: 1 mA x (1000 ohms) = 1 volt. The ratio of the control resistance to the output voltage R_{VC}/E_O, which in the present case is established as 1000 ohm/volt, is termed the "Control Ratio" of the power supply.

3-5 Deviations. To compensate for inherent component tolerances, the control ratio in all KEPCO CK power supplies is adjusted slightly smaller than 1000 ohm/volt. Also, a small error is introduced by the minute negative off-set voltage encountered at the output terminals when the voltage control is set to its maximum counter clockwise position. (Since $R_{VC} = 0$, in this case, we could expect, according to equation (4) that E_O would be zero). Both "inaccuracies" have been purposely designed into the power supply to facilitate precision adjustment of the programming ratio and are of no consequence in the ordinary operation of the power supply.

3-6 Adjustment. Resistance programming with precision decades or other highly accurate resistances require a control ratio accuracy comparable to the tolerances of the precision programming components. Two adjustments towards this end are necessary in the KEPCO CK Power Supply and described below.

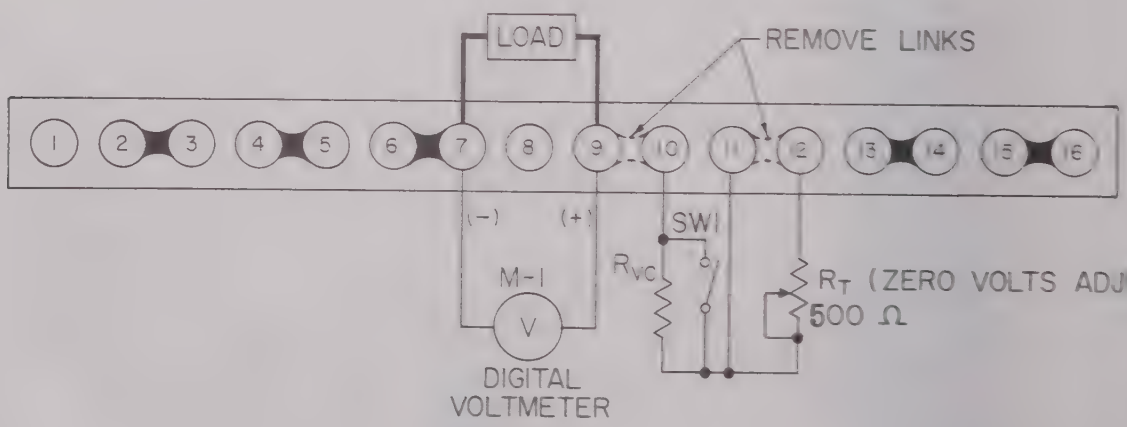


FIG. 3-2 CONNECTIONS FOR PRECISION PROGRAMMING RATIO ADJUSTMENT

3-7 PROCEDURE

a) Equipment Required:

1) Precision digital or differential voltmeter.

2) Precision resistor, 0.1% or better. (The value is not critical, but must be known precisely. For every 1000 ohms, 1 volt output will appear across the voltmeter. This resistor will be externally connected as R_{VC}).

3) Adjustable, wire-wound resistor, 500 ohms. (A 15-turn wire-wound "TRIMPOT" potentiometer or its equivalent is recommended. This trimmer will be used as a zero adjustment.

4) Single Pole, single throw switch.

b) With line power removed from the power supply, remove links on the rear barrier strip between terminals (9) and (10) and between terminals (11) and (12).

c) Connect external components as shown in FIG. 3-2.

d) Turn line power "on". With SW-1 open, and R_{VC} say 5000 ohms, (known) approximately 5 volts output voltage will be read out on the digital voltmeter.

e) Adjust R42 Calibrate Control, for precisely 5.00 volts. (On printed circuit amplifier board, FIG. 2-2). Close SW-1. Adjust R_t for precise Zero on the voltmeter.

f) Repeat (e) until no further readjustment on R42 or R_t is necessary.

3-8 PROGRAMMING OUTPUT VOLTAGE WITH EXTERNAL RESISTANCE

3-9 General. The output voltage may be programmed or controlled over its entire range at the nominal 1000 ohm/volt programming ratio of the CK power supplies. (If a precise ratio is desired, refer to Paragraph 3-3). In this mode of operation, the internal voltage control (R_{VC}) is disconnected and an external or remote voltage control resistance is substituted. This resistance may take the form of a precision decade, fixed and step-switch controlled resistors or another potentiometer.

3-10 The relationships governing this type of programming are given by

$E_o = R_{vc} \frac{E_r}{R_r}$ (Eq. 1) and since $\frac{E_r}{R_r} = I_b$ (Eq. 2) we can combine Eq. (2) and Eq. (1), to get $E_o = I_b R_{vc}$ (Eq. 4). Since I_b is (a nominal) 1 mA, 1000 ohms control resistance must be provided for each volt of output. This corresponds to a programming ratio of 1000 ohm/volt.

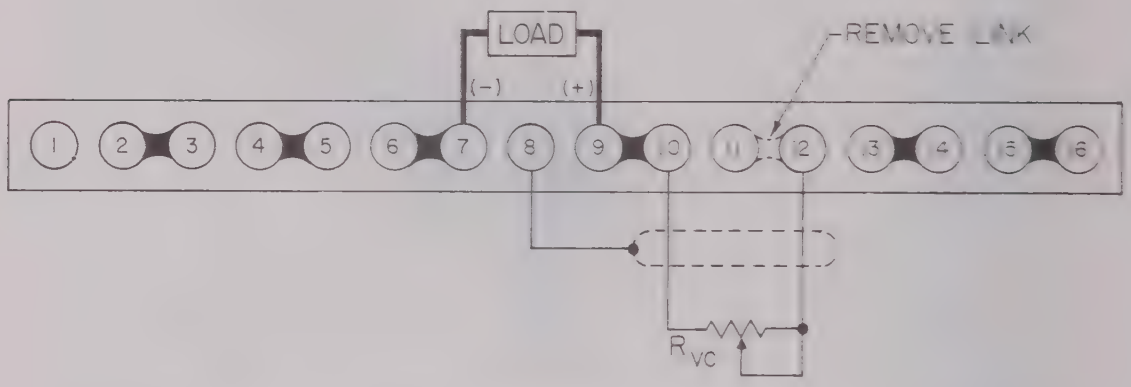


FIG. 3-3 CONNECTIONS FOR RESISTANCE PROGRAMMING

3-11 PROCEDURE

a) Remove link between terminals (11) and (12) at the rear barrier strip.

b) Using a shielded, twisted pair of wires, connect the external control resistance to terminals (10) and (12). Connect the shield to terminal (8).

NOTE: a) All resistors, used for external programming, must be high quality, wire wound units with a temperature coefficient of at least 20 ppm. Step-switch devices must be of the "make before break" variety.

b) The quiescent DC current through the programming resistors is the bridge current, or 1 mA. However, when programming large voltage excursions an error current flows. The power stored in the output capacitors will try to discharge partially through the control resistance and large peak currents may result. Therefore, the power dissipation rating of the control resistance should be several times that of the actual power dissipated under quiescent DC conditions.

3-12 PROGRAMMING OUTPUT VOLTAGE WITH EXTERNAL VOLTAGE

3-13 The output voltage of the KEPCO CK Power Supply can be controlled by an external, variable voltage source which replaces the fixed, built-in reference source. This mode of operation is referred to as "Voltage Programming". It can be mathematically expressed by referring to basic equation (1):

$$\frac{E_r}{R_r} = \frac{E_o}{R_{vc}} . \quad \text{Solving for } E_o, \; E_o = E_r \frac{R_{vc}}{R_r} .$$

Denoting the variable programming source E_i and substituting for E_r we have:

$$E_o = -E_i \frac{R_{vc}}{R_r} \text{ (equation 4)}$$

Consequently, if E_i is varied in this expression and the ratio $\frac{R_{vc}}{R_r}$, which represents the closed loop gain of the system, is held constant, the output voltage E_o will vary linearily with E_i. Referring back to equation (4) we see that the expression is similar to the inverted amplifier equation for an operational amplifier. The voltage programmed power supply does in fact become a unipolar power amplifier with potentially very high power gain but with limited frequency response. (Refer to FIG. 3-4). The limited frequency response is largely due to the effect of the output capacitor C_o acting as a low-pass filter and preventing the output voltage (E_o) from varying rapidly. The range in which E_o can be varied is limited only by the maximum output voltage of the power supply and by the leakage current of the comparison amplifier. This leakage current is in the order of 10 μA flowing opposite to I_b, the programming current. It is therefore desirable to select I_b sufficiently high, in order to keep the leakage current insignificant with respect to I_b. For critical applications, the leakage current can be compensated out. The "Kepco Power Supply Handbook" provides information towards this end.

3-14 A practical example to illustrate the method of voltage programming will be given below:

EXAMPLE: A Kepco CK 36-1.5 power supply is to be programmed over its full range from a variable, unipolar source, with a peak output voltage of 3 volts and capable of delivering 1 mA of stable current. The internal voltage control and therefore the programming ratio of 1000 ohm/volt are to be retained. The programming ratio of 1000 ohm/volt pertains to the programming source as well. Consequently the coupling resistor (R_i) must be 3000 ohms.

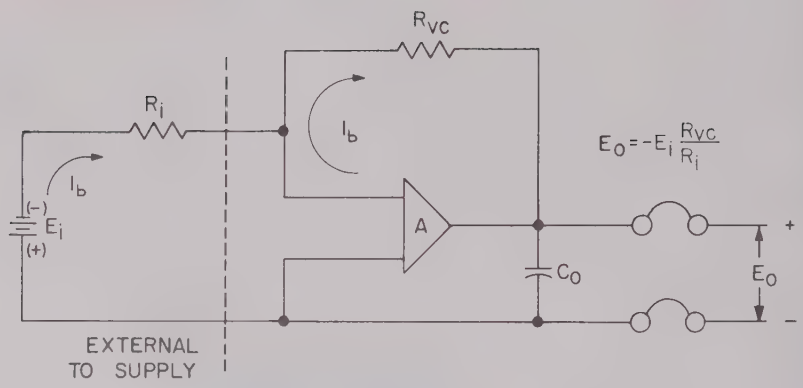


FIG. 3-4 VOLTAGE PROGRAMMING, OPERATIONAL NOTATION

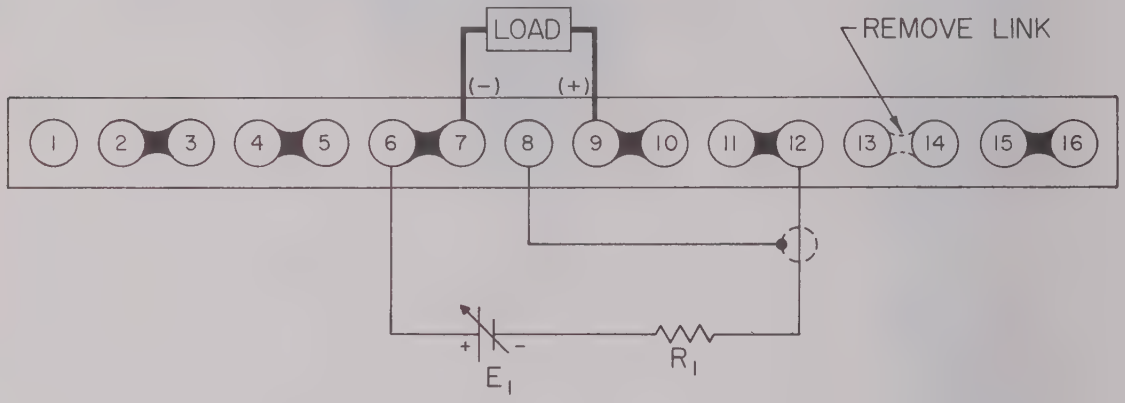


FIG. 3-5 CONNECTIONS FOR VOLTAGE PROGRAMMING

3-15 PROCEDURE (Refer to FIG. 3-5)

a) Remove link between terminals (13) and (14) on the rear barrier strip.

b) Connect selected components as shown, observe polarities.

c) Set the amplitude or voltage control of the programming source to the maximum selected programming voltage (3V).

d) Turn on the power supply to be programmed and the external programming source. Adjust the "Voltage Control" of the power supply to the selected maximum output voltage (36V).

e) The output voltage will now track variations in the programming voltage at the proportion established, (1:12).

3-16 REMOTE ERROR SENSING

3-17 GENERAL. The error sensing terminals (6) and (10), at the rear barrier strip are the input terminals to the regulating system of the power supply and are normally connected to the output terminals, providing specified regulation at these points. Voltage drops due to load current in the load connecting wires would degrade regulation directly at the load. Remote Error Sensing can be used to compensate for voltage drops up to 0.5 volts in each load wire, and provide specified regulation directly at the load.

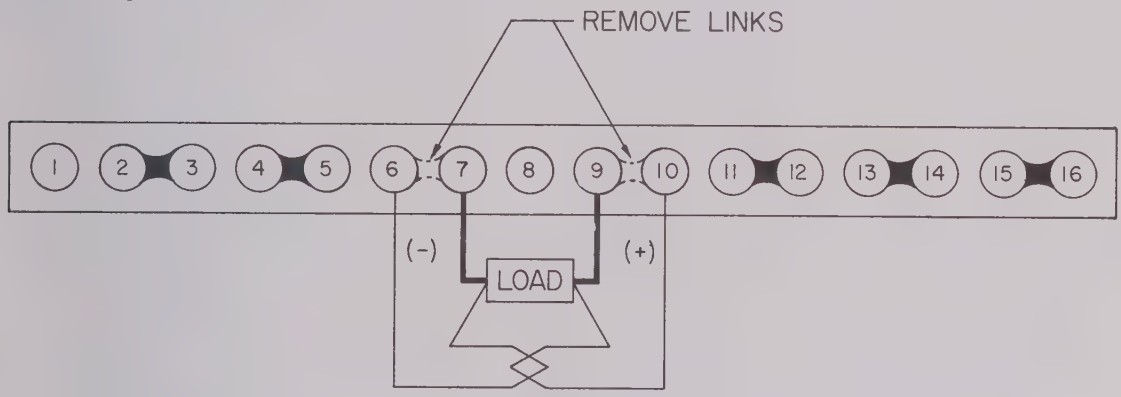


FIG. 3-6 CONNECTIONS FOR REMOTE ERROR SENSING

3-18 PROCEDURE (Refer to FIG. 3-6)

a) Remove links between terminals (6)-(7) and (9)-(10) on the rear barrier strip. These links remove the error sensing from the output terminals and must be replaced when Remote Error Sensing is not being used.

b) Connect a twisted wire pair to the error sensing terminals (6) and (10). Observe polarity. Terminal (10), the positive error sensing terminal, must go to the positive side of the load, while terminal (6), the negative error sensing terminal must be connected to the negative side of the load. The error sensing wires carry the error signal and the bridge current but not the load current and may therefore be constructed from relatively small gauge wires, such as No. 20 AWG.

CAUTION: 1) OPEN LOAD LEAD. Before the power supply is turned on, make absolutely certain that the load wires are connected securely. If a loadwire should become disconnected while error sensing is used, the regulator will attempt to maintain load current flow through the sensing wires and damage to the power supply circuitry will result.

2) OPEN SENSING LEAD. Do not allow the power supply to operate with an open circuit between sensing terminals and their respective load terminals. This would degrade the regulation severely, and cause the output voltage to rise and increase the output ripple sharply. The output voltage rise in such a case is limited automatically to approximately 1.5 volts to protect the load.

3) Twisted loadwires of ample diameter are helpful in reducing transient recovery time. Stability problems when working into other than resistive loads can often be resolved be connecting a capacitor directly across the remote load.

3-19 PROGRAMMING OUTPUT CURRENT WITH EXTERNAL RESISTANCE

3-20 The output current of the CK power supply may be controlled externally by disconnecting the internal "Current Control" potentiometer and substituting an external control resistor. This external control may be fixed, stepped, or continuously variable, and it may be remotely located. If fixed resistors are used to step-control the current output, the switches used must be of the "make before break' variety. (Shorting Contacts)

CAUTION: The absolute maximum of the output current is normally limited to 2% above the maximum rated output current of the power supply with its "Current Control" at maximum clockwise position. If an external control is used, it must be similarly adjusted with the external control at the maximum position. When returning to normal operation using the internal control it must again be returned to its previous adjustment. (Refer to Paragraph 5-12)

3-21 KEPCO CK power supplies Model CK 2-8(M) and Model CK 8-5(M) use 0.5 volt sensing voltage and a 500 ohm "Current Control" potentiometer, resulting in a current programming ratio of 1000 ohm/volt. Models CK 18-3(M), CK 36-1.5(M), CK 40-0.8(M) and CK 60-5(M) use 1 volt of sensing and a 1000 ohm control, retaining thereby the 1000 ohm/volt programming ratio. Any external combination of resistors or any continuous control resistance, equal to 500 ohm (or 1000 ohm depending on the individual model) will program the output current of the CK supply through its entire range. An example of a step control programming set-up is given in the procedure below.

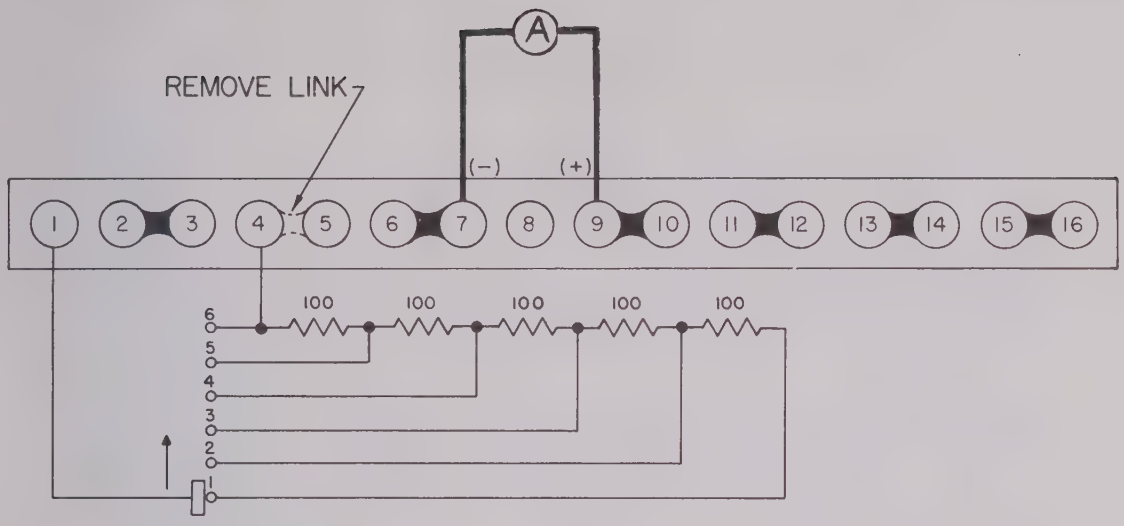


FIG. 3-7 CONNECTIONS FOR RESISTANCE PROGRAMMING (CURRENT MODE)

3-22 PROCEDURE

3-23 EXAMPLE: The output current of a CK 8-5(M) is to be programmed in steps of 1 Ampere up to the maximum output current of the unit.

a) Since we need 500 ohms total resistance for R_{CC}, five 100 ohm resistors are connected to a 6 position switch (with shorting contacts) as shown in FIG. 3-7.

b) Connect an ampere-meter as a short circuit across the output terminals of the power supply.

1) The range of the ampere-meter must be sufficient to include the maximum output current of the unit.

2) The desired accuracy of the output current steps, will depend upon the accuracy of the meter.

3) The connecting leads to the meter should be short and sufficient in diameter to carry the maximum current.

c) Turn power supply "on". With SW-1 in position as shown, adjust R40 (Refer to FIG. 2-2 for location) to the exact maximum output current (5A).

d) All successive positions will yield the proportional output current,

pos 1) = 5 A	pos 4) = 2 A
pos 2) = 4 A	pos 5) = 1 A
pos 3) = 3 A	pos 6) = 0 A

3-24 PROGRAMMING OUTPUT CURRENT WITH EXTERNAL VOLTAGE

3-25 The output current of the CK power supply can be voltage programmed in a manner similar to that described in Paragraph 3-12. The fixed reference supply (E_r and R_r) in the current bridge circuit is removed and replaced by a variable programming source E_i with coupling resistor R_{rc}. The output current will vary in accordance with the equation $I_o = \frac{E_i R_{cc}}{R_{rc} R_s}$, where R_s is the current sensing resistor and R_{cc} the Current Control. If the original programming ratio is to be maintained, the programming source must be capable of supplying 1 mA of stable current. The value of R_{rc}, the external coupling resistor, is found by multiplying the maximum programming voltage (E_i) by the control ratio: $R_{rc} = E_i$ (1000 ohm/volt of sensing). R_{rc} should be variable to be able to adjust the output current to its maximum rated value. An example will be shown below to illustrate the application of this mode of operation.

3-26 EXAMPLE: A CK 18-3(M) is to be voltage programmed in the current mode from zero to full output current. The programming source is a unipolar, variable supply, capable of delivering at least 1 mA and with a maximum voltage of 25 volts.

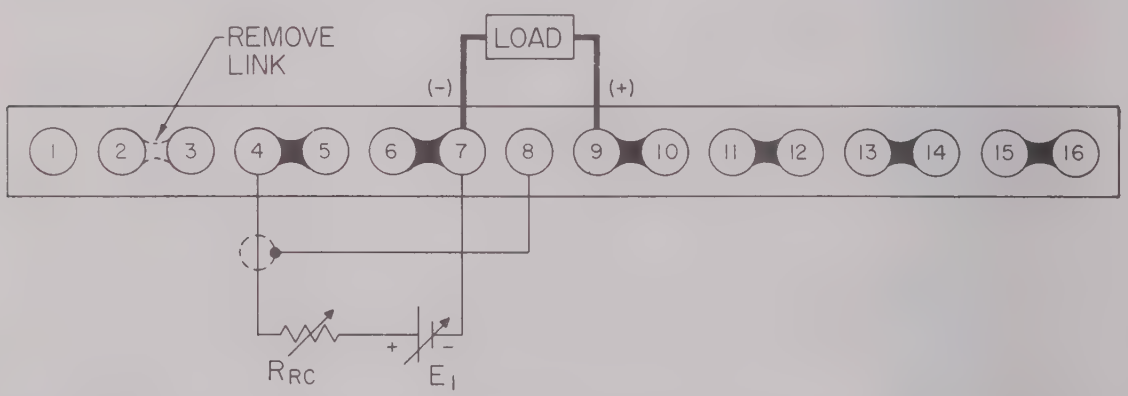


FIG. 3-8 CONNECTIONS FOR PROGRAMMING OUTPUT CURRENT WITH EXTERNAL VOLTAGE

3-27 PROCEDURE:

a) Select the external coupling resistor R_{rc}. Since the external programming source is capable of delivering 1 mA, the 1000 ohm/V control ratio can be maintained. R_{rc} is found by multiplying the maximum amplitude of the programming source (E_i max.) by this ratio:

$$E_i \text{ max.} \times \text{Programming Ratio} = 25 \times \left(\frac{1000 \text{ ohm}}{V_s}\right) = 25000 \text{ ohm}$$

We will split resistor into a fixed 20000 ohm part and an adjustable 10 K ohm potentiometer.

b) Connect the programming set-up as shown in FIG. 3-8. Turn both, "Voltage Control" and "Current Control" on the front panel of the power supply fully clockwise.

c) Connect a short circuit, consisting of an accurate ammeter with short connecting leads of adequate diameter, and able to carry the maximum output current of the power supply, across the output terminals.

d) Set the programming source to its maximum output voltage and R_{rc} to its maximum resistance value.

e) Turn power supply and programming source "on". With R_{rc} at its maximum resistance value, the output current as read out at M-1 should be below its maximum rated value. Adjust R_{rc} in the direction of decreasing resistance until output current will reach its rated maximum value. The programming source will now vary the output proportionally.

3-28 OUTPUT CURRENT REGULATION USING EXTERNAL SENSING

3-29 External sensing for the purpose of superior regulation at low currents may be used with CK power supplies. In the internal "Current Regulation" Mode, an internal sensing resistor R_S is used to generate a voltage drop proportional to the load current flowing through it. This voltage drop as applied to the current comparison bridge, constitutes the output voltage for comparison purposes. This voltage drop across R_S changes with load-current, since I_L is made variable in the CK supplies. Optimum regulation however can only be achieved over a comparatively narrow range of V_S, the voltage across sensing resistor R_S, so that in a variable current supply a compromise in the selection of R_S must be made. If external sensing is used, R_S can be selected close to its optimum value and excellent regulation of small load current over a narrow range can be achieved.

3-30 In the external sensing mode, the voltage comparison bridge is being used to regulate current. The current bridge is inactive and consequently automatic cross-over does not take place and only the "Voltage" VIX indicator will energized. The practical application of this mode of operation will best be shown by an example.

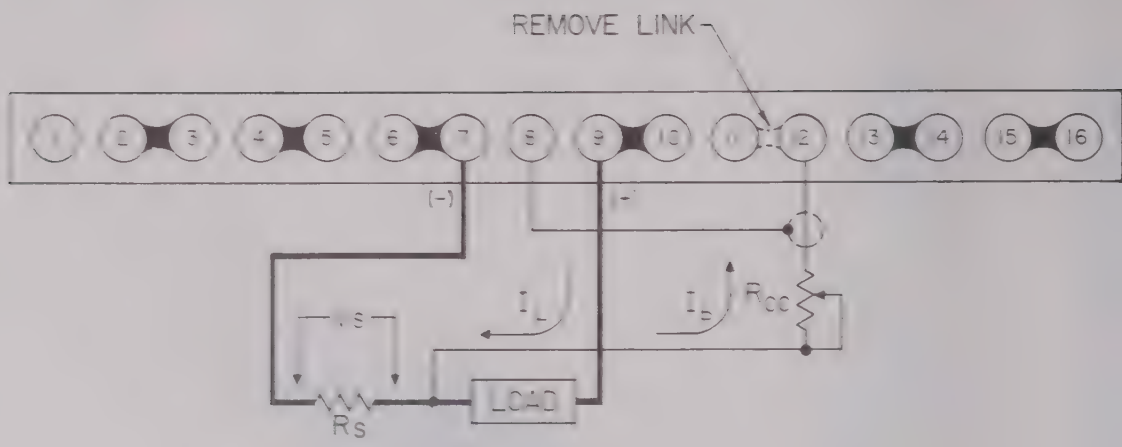


FIG. 3-9 CONNECTIONS FOR CURRENT REGULATION USING EXTERNAL SENSING

3-31 EXAMPLE:

a) A constant current of 11 mA is needed. The power supply available is a Kepco CK 2-8(M). Since the current required is out of this supplies' regulation range (0.2% - 100%), external sensing will be used.

b) A 1 volt sample voltage across R_S will be selected, requiring a coupling resistor R_c of 1000 ohms, according to the established control ratio of the CK supply (1000 ohm/volt.)

c) R_S, the sensing resistor is calculated by Ohm's Law:

$$R_S = \frac{V_S}{I_O - I_b}, \quad R_S = \frac{1 \text{ volt}}{(0.011A - 0.001A)} = 100 \text{ ohm.}$$

The power dissipated in R_S, is $P_{diss} = 0.01$ watt. A 100 ohm, W.W., 1 W resistor with a T.C. of 20 ppm or better will be used.

d) Connect the selected components as shown in FIG. 3-9. If R_c is made variable, the output current can be varied with it over an approximately 1:10 range. At 1 mA I_O however, the supply will lose control, because the control current which is in the order of 1 mA, will tend to cancel the load current through the sensing resistor, producing a large error signal at the comparison bridge.

CAUTION: When using external sensing, the load must be connected at all times. Since the power supply is operating with the voltage comparison bridge, opening the load wires would appear to the error amplifier as an infinite resistance load, and the maximum unregulated voltage will appear at the output.

3-32 SERIES OPERATION OF CK POWER SUPPLIES

3-33 KEPCO CK power supplies can be series connected for increased voltage output provided the specified limits on voltage to chassis are not exceeded. When series connected, the supplies should be protected by means of a semi-conductor diode across the output terminals of each supply. The peak-inverse voltage of these diodes must be at least as large as the output voltage of the supply to which they are connected. The continuous current rating of the protective diodes must be greater than the maximum output current of the inter-connected supplies.

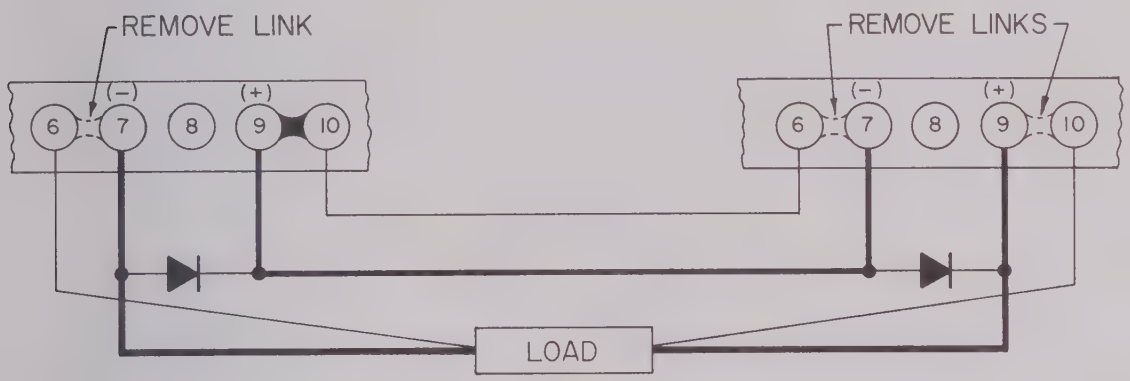


FIG. 3-10 CONNECTION FOR IN-SERIES OPERATION

3-34 PROCEDURE

a) Connect load to power supplies as shown in FIG. 3-10. Keep voltage drops in the load wires as low as possible by selecting the gauge as heavy as practicable.

b) Connect protective diodes across their respective output terminals.

c) Remove jumper-links as shown and connect error sensing leads. These leads carry negligible current and may be light gauge wire. (#20 AWG)

d) Turn both supplies on, and adjust voltage on either control as required.

3-35 PARALLEL OPERATION OF CK POWER SUPPLIES

For the purpose of obtaining higher load current, paralleling of KEPCO CK Power Supplies is possible. Several methods can be used, two of the most common ones are given below:

3-36 MASTER-SLAVE CONNECTION. In this method of paralleling, the pass-elements of both units are effectively combined and driven from a common control derived from the master supply amplifier. Up to three supplies can be operated in this manner, beyond this number, other methods must be used. (Refer to Paragraph 3-38)

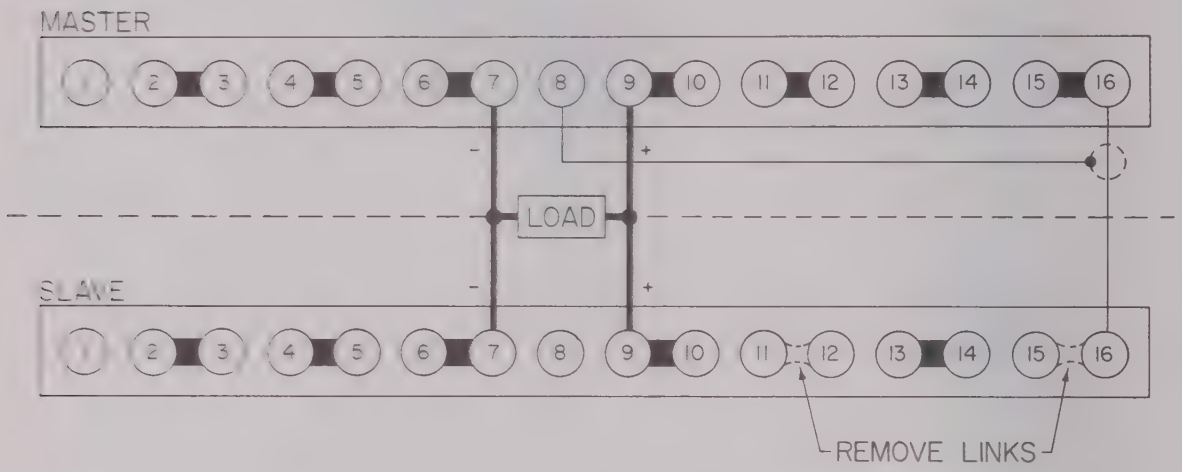


FIG. 3-11 SERIES OPERATION, MASTER-SLAVE CONNECTION

3-37 PROCEDURE (Refer to FIG. 3-11)

a) Remove jumper links between terminals (11)-(12) and (15)-(16) on the rear barrier strip of the slave unit. Join terminals (16) of both units with a shielded wire and connect the shield to terminal (8) on the master unit.

b) Connect load with equal length of wire from each power supply to insure optimum current sharing. (This becomes especially important when load currents close to the combined maximum current limits are required).

c) Connect remote error sensing, if required, from the error sensing terminals of the master unit to the load as described in Paragraph 3-16.

d) Connect power supplies to line simultaneously by means of a common power switch.

3-38 AUTOMATIC CROSS-OVER CONNECTION. This method does not involve any special interconnections, except for common AC powerline switching and connection of the load with equal lenghts of wire. Each supply is set to the desired output voltage with its respective "Current Control" set to its maximum clockwise position. After turn-on, one of the supplies will be at a slightly higher output voltage than the rest, (Supply #1). It is this supply that will deliver all the current up to its own "Current Control" setting. As the load is increased, the supply with the second highest output voltage will take over and deliver the additional current up to its "Current Control" setting, and so on, until all parallel supplies are sharing the load current. The "Current Controls" of all supplies can now be set to achieve approximately equal current sharing.

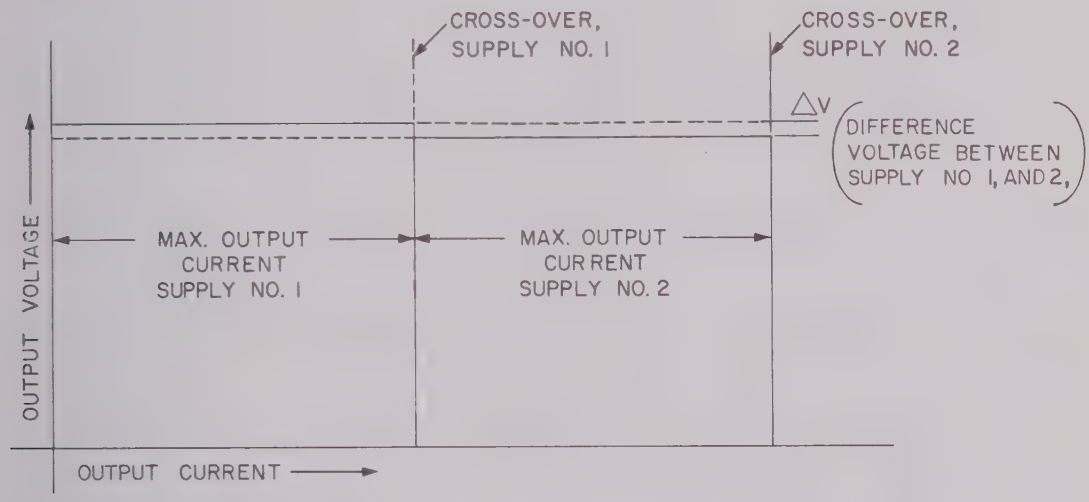

CROSS-OVER, SUPPLY NO. 1
CROSS-OVER, SUPPLY NO. 2
△V
DIFFERENCE VOLTAGE BETWEEN SUPPLY NO 1, AND 2,
MAX. OUTPUT CURRENT SUPPLY NO. 1
MAX. OUTPUT CURRENT SUPPLY NO. 2
OUTPUT VOLTAGE
OUTPUT CURRENT

FIG. 3-12 AUTOMATIC CROSS-OVER, CK POWER SUPPLIES

FIG. 3-12 shows in diagram-form how power supplies operate in AUTOMATIC CROSS-OVER mode. It will be obvious from the diagram that since the output voltages are never exactly equal, a "delta V" exists, which would, if an attempt were made to measure load regulation over the whole range, add to the "regulation delta V" and would result in erroneous readings. Load regulation therefore can be measured in the individual output current bands only.

NOTE: When paralleling CK power supplies, care should be exercised to avoid turning only one of the voltage controls close to zero. This precaution will prevent excessive currents in the control potentiometer as its limiting resistance is lowered.

SECTION IV - THEORY OF OPERATION

4-1 GENERAL

4-2 This section contains a description of the major circuitry of the Kepco Model CK power supply. The purpose of the analysis is to provide the user with a functional understanding of the unit and form thus a basis for successful operation and maintenance.

4-3 The main schematic (FIG. 5-4) and the control section drawing(FIG. 4-1) should be used as a reference for the following circuit description.

4-4 CIRCUIT DESCRIPTION

4-5 AC Input Circuit. AC power is introduced to the unit through a three wire safety line cord with a three prong plug. When AC line switch (S101) is closed, T201, T401 and fan B201 receive power immediately. Fuse 101 protects the input circuit from overcurrent.

4-6 Main DC Power Supply. The main DC power is derived from the secondary of T201. The conventional full wave rectifier (CR202, CR203) is working into a capacitor filter (C203). The main DC Power Supply delivers the output current and the operating voltages for the pass elements.

4-7 Pass Element Circuitry. The pass elements are connected in series with the negative output lead, so that the unregulated voltage from the rectifier circuit is divided between these power transistors and the DC cutput of the Power Supply. By properly "driving" the pass transistors, their equivalent resistance changes and therefore the voltage drop across them is affected in such a way as to maintain the output voltage constant. The base drive necessary for this action is supplied by a driver, which itself is driven by a pre-driver (Q-6). The pre-driver gets its base drive from the output of either the voltage or the current comparison amplifier.

4-8 Auxiliary Supplies.

a) Return Supply. This full wave, capacitor filtered supply is derived from the identical winding on T201 which supplies the main DC power. It consists of silicon rectifiers CR202 and CR203 and filter capacitor C202. The return supply has the function of providing the turn-off bias for the series pass elements and the main driver.

b) Pre-Driver Collector Supply. This full wave, capacitor filtered supply is derived from a winding on T401 and consists of CR416, CR417 and C410. It delivers the collector voltage for the pre-driver stage Q6.

NOTE: The Model CK 2-8(M) does not have a separate pre-driver collector supply, the pre-driver collector voltage is directly derived from the main DC supply. This model uses the winding on T401 as well as CR416, CR417 and C410 as the return supply.

4-9 CONTROL SECTION (Refer to FIG. 4-1)

4-10 The control circuitry of the CK power supply is located on PCB-1, assembly A1. This assembly is in the form of a printed circuit board, whose connector P1 connects it to the main chassis and auxiliary circuitry through J2. Electrically the control circuitry consists of several interrelated sections which are described in detail below.

a) Control Circuit Power Supply. (Refer to FIG. 4-1) This highly regulated supply delivers the fixed operating voltages for the voltage mode and current mode amplifiers, as well as the reference voltages for the voltage mode and current mode comparison bridges. It is derived from a centertapped winding on T401 and consists of a full-wave rectifier with capacitor-input filter (CR407,CR408, C503), a series current regulator stage (Q1), and the zener regulator diodes CR10 and CR11 for the minus and plus 18 volts respectively. The negative and positive 18 volt supplies are filtered by C313 and C314. The voltage reference diode (CR14) is fed from the negative 18 V source and the current reference (CR15) from the positive 18 V source.

b) Comparison Bridges. In the Kepco CK power supplies two separate control channels are used, each with its own comparison bridge circuit and its associated error signal amplifier. The voltage mode comparison bridge senses the output voltage across the output terminals of the power supply. (Except when using remote error sensing, then the bridge senses directly across the load.) The current mode comparison bridge senses the voltage across the current sensing resistor R_S. Each bridge compares its sensing voltage to its own reference voltage.

c) Current Mode Amplifier. An unbalance in the current mode comparison bridge results in an error signal which is transferred to input transistor Q10, and amplified by Q9 and Q13. It arrives at gate transistor Q5 as a large negative excursion.

d) Voltage Mode Amplifier. An unbalance in the voltage mode comparison bridge results in an error signal transferred to input transistor Q2 and is amplified by Q3. It arrives at the base of gate transistor Q4 as a large negative excursion.

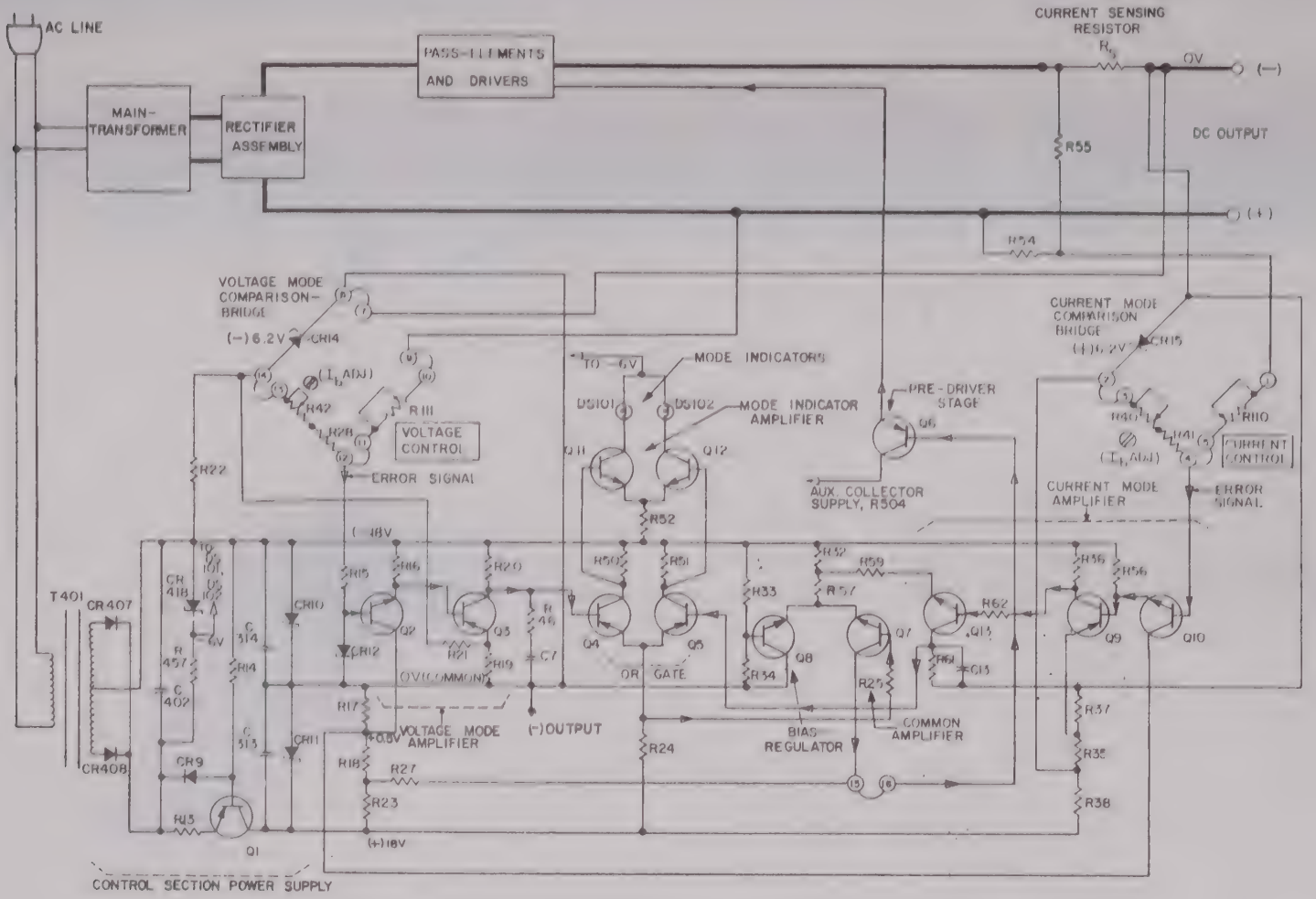
e) OR Gate. The gate transistors Q4 and Q5 act like a two pole switch. The transistor with the larger negative signal on its base will conduct, cutting the other one off. The transistor which conducts, be it Q4 or Q5, will in turn drive its associated mode-indicator amplifier companion into conduction, which then will energize either DS101 or DS102, the mode indicator.

f) Common Amplifier and Driver. The signal predominant in the above description, may it originate in the voltage or current mode comparison bridge, will be further amplified by Q7 and transferred to the pre-driver Q6 which, as an emitter-follower, supplies the necessary drive to the main-driver and the pass-elements.

g) Q8 is a bias-setting stage for the rest of the transistors in the amplifier. Its base provides a convenient point for the start of a DC analysis of the system.

h) Automatic Crossover Operation. Automatic mode switching in the CK power supplies is caused by an unbalance in one of the comparison bridges as discussed above. The operating mode of the power supply is therefore mutually dependent upon the load resistance and the setting of the voltage and current controls. The "Crossover Point" is defined by the ratio of the voltage and current setting which equals the load resistance. If for example, the load current due to a specific load resistance, is larger than the current control setting of the supply, the current mode comparison bridge will produce the larger error signal and the power supply will automatically switch to current mode operation as described above. At any load resistance value causing an output current smaller than the set value at the current control, the power supply will operate in voltage mode.

i) VIX Crossover Signals. Automatic Crossover from one mode of operation to the other is indicated by two signal lamps located on the front panel. (DS101, DS102). The crossover signal is also available at two jacks on the rear of the unit. This signal may be taken out and converted into a heavy duty relay closure for signal purposes by means of the KEPCO VIX-1C Relay or any other device sensitive to a signal of ± 8V DC (nominal), 1 mA.



NOTES:

1. NUMERALS ENCLOSED ◯ ARE TERMINAL NO'S AND PART OF TB1.
2. VOLTAGES IN REFERENCE TO MINUS (−) OUTPUT TERMINAL.
3. ⟶ = ERROR SIGNAL - FLOW.

FIG. 4-1 CONTROL SECTION, CK POWER SUPPLIES, SIMPLIFIED.

SECTION V - MAINTENANCE

5-1 GENERAL

5-2 This section contains information for the maintenance, internal adjustments and test-measurements of the KEPCO Series CK Power Supply.

5-3 PRECAUTIONS

5-4 No part replacements or adjustments, other than described in this section, should be made on the instrument. Replacements or adjustments made without understanding the effects may cause serious damage to the Power Supply.

5-5 TEST EQUIPMENT REQUIRED

5-6 The following is a listing of the test equipment required to measure some important parameters and make all necessary adjustments on the KEPCO CK Power Supplies:

a) AC Line Step Device or variable transformer capable of adjusting the power line from 105 V to 125 V AC and rated to deliver the maximum input current for the instrument under test. (Refer to Table 1-1).

b) Resistor load, adjustable to load the power supply to 10%, 50% and 100% in both, voltage and current operating modes and equipped with a shorting switch.

c) Voltage Monitor. Regulation Analyzer or, differential or digital voltmeter with a resolution of at least 1 mV and a range covering the maximum output voltage of the power supply under test.

d) RMS reading voltmeter for ripple monitoring, Ballantine Model 320A or equivalent.

e) Oscilloscope for output ripple observance. (Tektronix, Model 502B or equivalent).

f) Multimeter for measuring pass element voltage and general trouble shooting measurements. 20 K ohm/V, Weston Analyzer Model 980 or equivalent.

g) Precision DC ampere meter with a range covering the maximum output current of the Model under test. (Weston Model 931 or equivalent)

5-7 DISASSEMBLY (Refer to FIG. 1-3)

5-8 Internal adjustments, or maintenance problems may require partial disassembly of the unit. This is readily accomplished following the steps given below. Proceed in reverse order for re-assembly.

a) Case Removal.

1) Lossen and remove the six (6) phillips-head machine screws holding the case to the main chassis frame. Two of these screws are located on the top of the case and four on the bottom.

2) Slide case to the rear, pull line cord through the case.

b) Amplifier Board Removal.

1) Loosen and remove the four (4) sheet metal screws holding the board to the main chassis frame.

2) Loosen and remove the two (2) 10/32 machine screws on the bottom of the output capacitor to release the output leads going to the amplifier board.

3) Remove the printed circuit board mating connector from the amplifier board.

5-9 INTERNAL ADJUSTMENT PROCEDURES

5-10 The internal adjustments for maximum output current and voltage are located on assembly A1 as shown in FIG. 2-3 and Table 2-2. These adjustments vary the bridge current (I_b) in both, voltage and current comparison bridge. They are factory adjusted to a value 2% above the maximum rated voltage or current with the respective front panel controls fully clockwise. These controls require resetting only if previously changed for programming purposes or following replacement of related circuit components.

5-11 PROCEDURE, VOLTAGE CONTROL ADJUSTMENT

a) Remove case as described in paragraph 5-7.

b) Connect precision voltmeter of suitable range across the front or rear output terminals of the power supply. Turn both voltage and current front panel controls to their maximum clockwise position.

c) Turn power supply "on". Locate R42 "Maximum Voltage Control" on Assembly A1, (FIG. 2-3), and adjust output voltage to 2% above maximum rated value for the particular model, as observed on the external, precision voltmeter.

d) Replace case and holding screws.

5-12 PROCEDURE, CURRENT CONTROL ADJUSTMENT

a) Remove case as described in paragraph 5-7.

b) Connect a presicion ampere meter of suitable range across the rear output terminals of the supply. Turn the front panel voltage control to its maximum clockwise, and the front panel current control to its maximum counter clockwise position.

c) Turn power supply "on", and slowly turn the front panel current control clockwise until its maximum clockwise position is reached.

d) Locate "Maximum Current Adjust" control on assembly A1 (Refer to FIG. 2-3) and adjust output current to 2% above its maximum rated value for the particular model, as observed on the external precision ampere meter.

e) Replace case and holding screws.

NOTE: The following internal adjustments are precision factory set and should not be altered unless required by replacement of components associated with the controls.

5-13 PROCEDURE, CURRENT REGULATION COMPENSATOR ADJUSTMENT

5-14 Potentiometer R64 in conjunction with its associated components R63 R54, R55) compensates for the internal loading of the voltmeter and the voltage bridge circuit when the power supply is operating in the constant current mode. Adjustment of this control is required only when R64 or its associated components must be replaced or when other changes of internal loading of the power supply take place.

a) Equipment Required: (Refer to Paragraph 5-5).

b) Connect test equipment as shown in FIG. 5-5).

c) With the power supply in its current regulation mode, and drawing approximately 10% of its maximum load current, measure the voltage drop across R_S.

d) Close S-1 and note delta V, the difference between the readings with S-1 open and closed. Rotate R64 as to minimize delta V on repeated tests.

5-15 TROUBLE SHOOTING

5-16 Contrary to popular opinion, modern, high performance power supplies today have reached a state of sophistication that requires thorough understanding of the problems involved in repairing complex, solid state circuitry. Servicing beyond simple parts replacements should consequently be attempted only by personnel thoroughly familiar with solid state component techniques and with experience in closed loop circuitry.

5-17 Trouble-shooting charts, showing resistance and voltage readings, are of very limited usefulness with feedback amplifiers and are not included here. Instead a detailed circuit description (Section IV), parts location diagrams, a simplified functional schematic of the control circuit section, and a main schematic with all significant voltage readings is presented.

5-18 The following basic steps in a case of power supply malfunctioning may also be found useful:

a) If power supply does not function at all: Check all powerline connections and fuses and make certain, power supply is connected to the correct line voltage (it is normally delivered for 115V AC operation).

b) If power supply fuses keep blowing or circuit breakers keep tripping, check pass-elements (without removing from assembly) by placing an ohm-meter across the emitter and collector. The emitter-collector resistance will be low in one direction and higher in the other, the ratio being approximately 5:1. If resistance is equally low in both directions (short circuit) the pass-element must be replaced.

c) If the power supply is basically functioning, but poor performance is evident, inspect the test set-up to make certain the source of the trouble is not external.

d) Poor regulation in any of the regulating modes is usually traceable to incorrectly connected loads or faulty measurement techniques. Perform measurements as described in Paragraph 5-20 and follow the connecting diagrams.

e) Oscillation of the output voltage or output current is often due to a load with a large inductive component. Twisted loadwires of sufficient diameter and held as short as practical, are often the solution to the problem. In severe cases, a capacitor, directly across the load will frequently help.

5-19 KEPCO Field Engineering Offices or the KEPCO Repair Department will be available for consultation or direct help in difficult service or application problems.

5-20 POWER SUPPLY MEASUREMENTS

5-21 Measurements of the significant parameters of a power supply is a requirement for incoming inspection, periodic maintenance, or after component replacement. Since some of the measurements require special techniques to insure correct results, suggestions for their performance are given below:

a) Instrumentation

Refer to Paragraph 5-5 for the necessary test equipment.

b) The proper location of the instrument leads when measuring regulation is of the utmost importance. Improperly placed leads may measure voltage drop due to contact resistance and load current flow and thus lead to incorrect results. This can be avoided by the four terminal network technique. FIG.S 5-3 to 5-6 show clearly how this technique is employed in regulation measurements. The principle is very simple but important: Do not measure voltage drops due to load current.

c) Voltage Regulation is defined as the amount of output voltage change resulting from a specified change in line voltage or from a change in load resistance. It can be expressed as an absolute change (ΔV) or as a percentage in reference to the total output voltage E_o;

$$\% \text{ Voltage Regulation} = \frac{\Delta V}{E_o} \quad (100\%)$$

d) Current Regulation is defined as the amount of output current change resulting from a specified change in line voltage or from a change in load resistance. It can be expressed as an absolute change (ΔI), or as a percentage in reference to the total output current I_o;

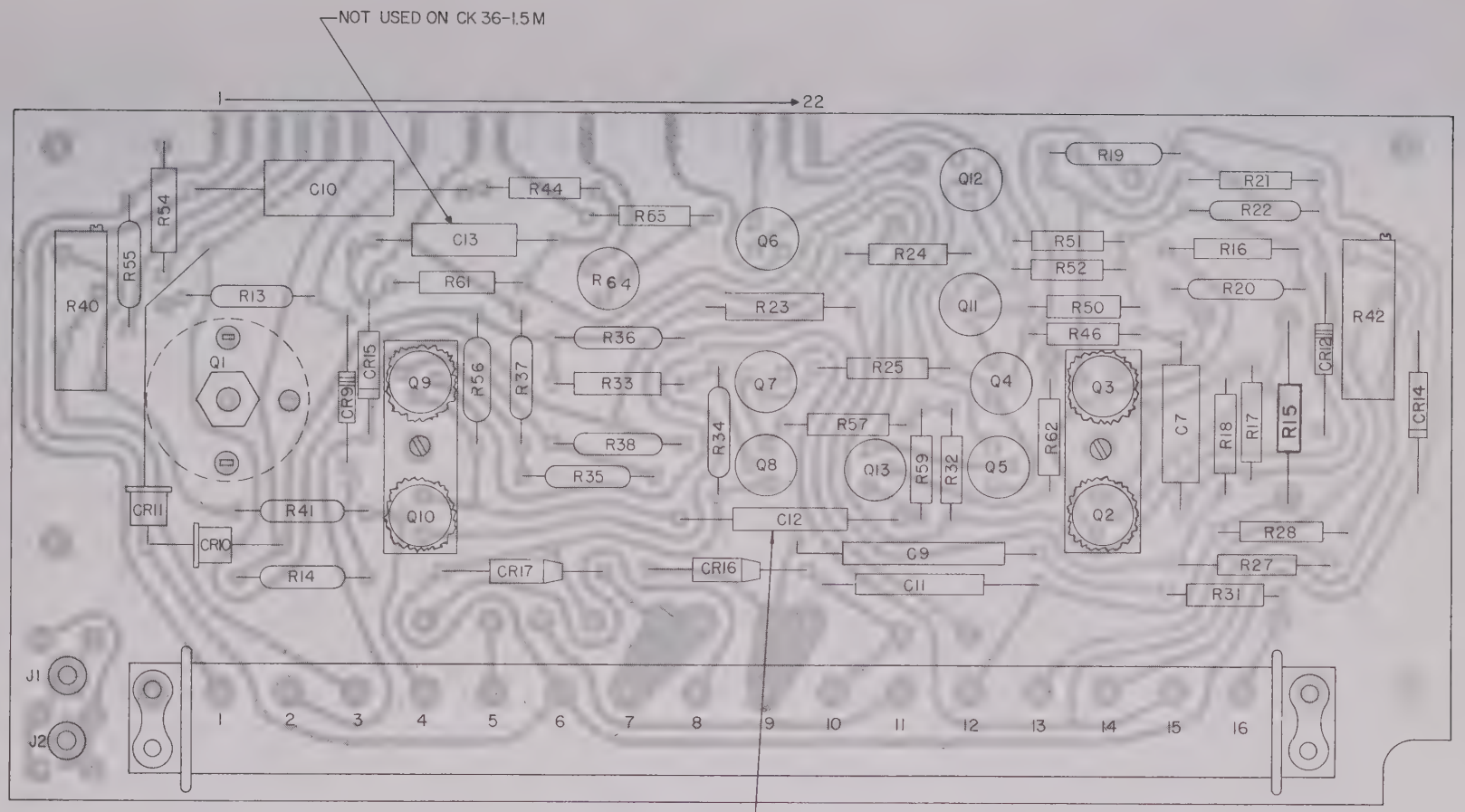
$$\% \text{ Current Regulation} = \frac{\Delta I}{I_o} \quad (100\%)$$

e) Ripple. An oscilloscope of suitable sensitivity, or a true RMS indicating meter may be used to measure the ripple at the output of the power supply. Suitable DC blocking must be provided externally, if the test instrument is not equipped with a suitable input. A 0.1 mfd capacitor of sufficient working voltage is generally adequate. If an oscilloscope is used only, the p-p/rms ratio, which for a pure sine wave is close to 2.83:1, can be approximated for the broken wave-form of a series regulator type power supply as 3:1.

CAUTION: Due to the low signal levels, ripple pick-up problems are especially accute when measuring ripple in the current mode. The use of completely shielded sensing resistors and load cables may be necessary to get valid readings.

The observed ripple current will depend, to some extent, upon the compliance (load) seen by the Power Supply when measurement is made. Specifically, the observed current ripple will show a slight increase when the load impedance is made so small as to approach the filter capacitor's reactive impedance. Under such circumstances, the filters are ineffective because they are "shorted" by the load.

This effect will have little influence upon normal operation of the Power Supply because the impedance of the load-connecting wires is usually sufficient to prevent the "shorting effect." (It will probably be noticed only when extremely small "crowbar" short-circuit loads are employed, as in testing.) For specification purposes, the minimum compliance voltage for ripple measurements is set at 0.5V DC.



NOTE:
USE FOR MODELS:
CK 18-3M
CK 8-5M
CK 60-0.5M
CK 36-1.5M
CK40-0.8M
CK 2-8M

NOTE:
C12 NOT USED FOR MODELS:
CK8-5M
CK2-8M

FIG 5-1 COMPONENT LOCATION, PCB-1

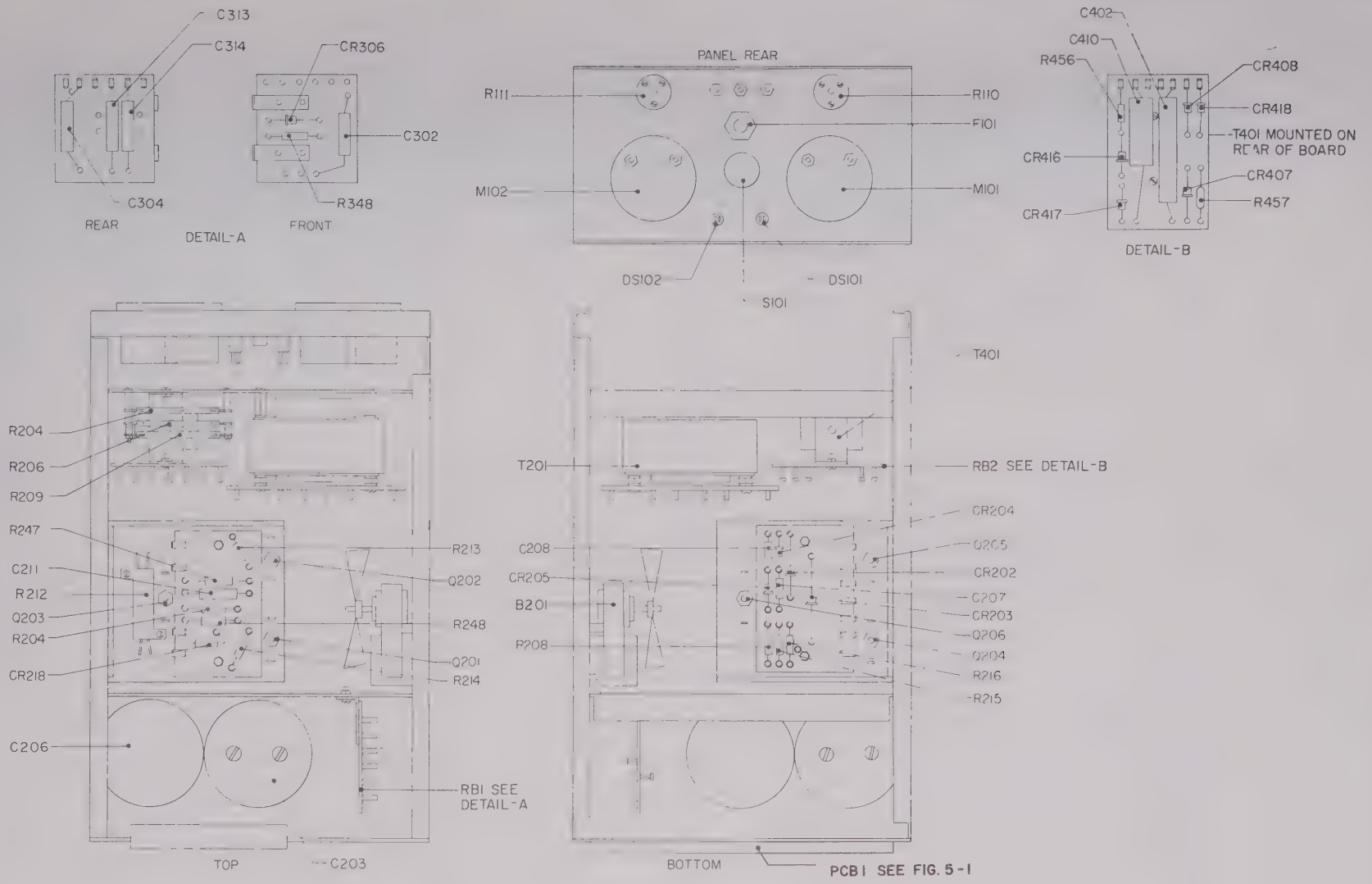


FIG. 5-2 COMPONENT LOCATION, MAIN CHASSIS AND SUBASSEMBLIES

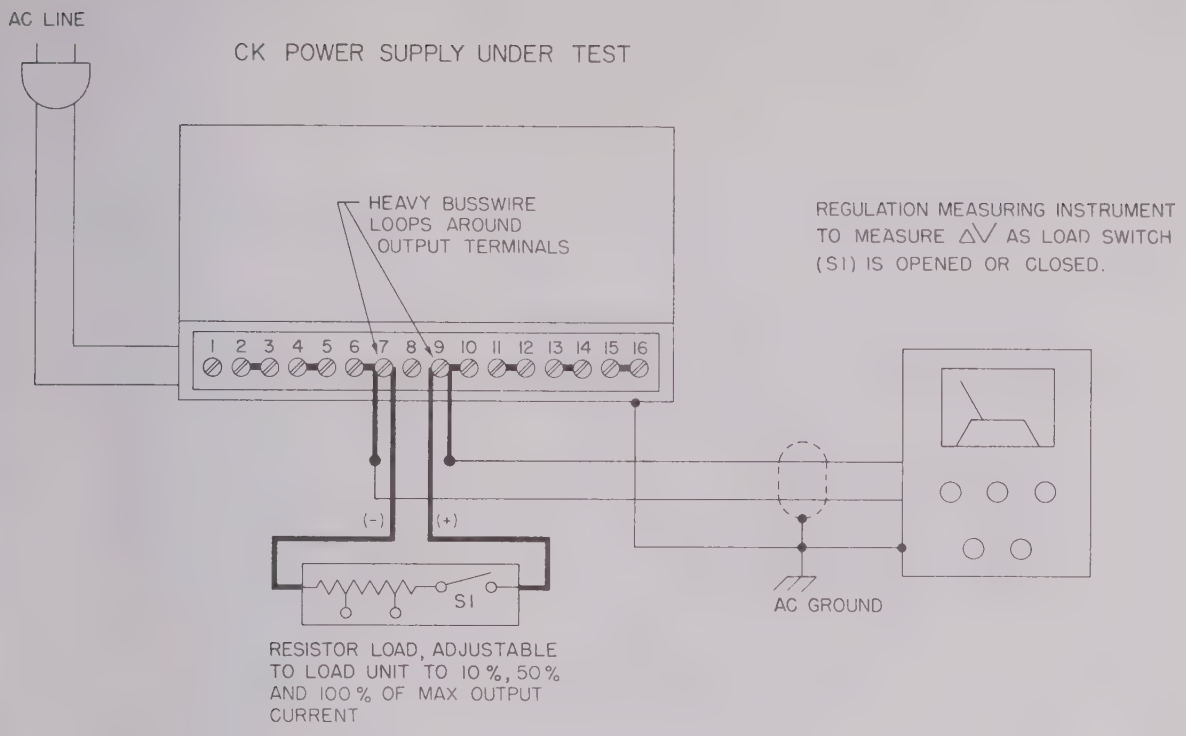

AC LINE
CK POWER SUPPLY UNDER TEST
HEAVY BUSSWIRE LOOPS AROUND OUTPUT TERMINALS
REGULATION MEASURING INSTRUMENT TO MEASURE ΔV AS LOAD SWITCH (S1) IS OPENED OR CLOSED.
1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16
(-)
(+)
S1
AC GROUND
RESISTOR LOAD, ADJUSTABLE TO LOAD UNIT TO 10%, 50% AND 100% OF MAX OUTPUT CURRENT

FIG. 5-3 MEASURING LOAD REGULATION (VOLTAGE MODE) WITHOUT REMOTE ERROR SENSING.

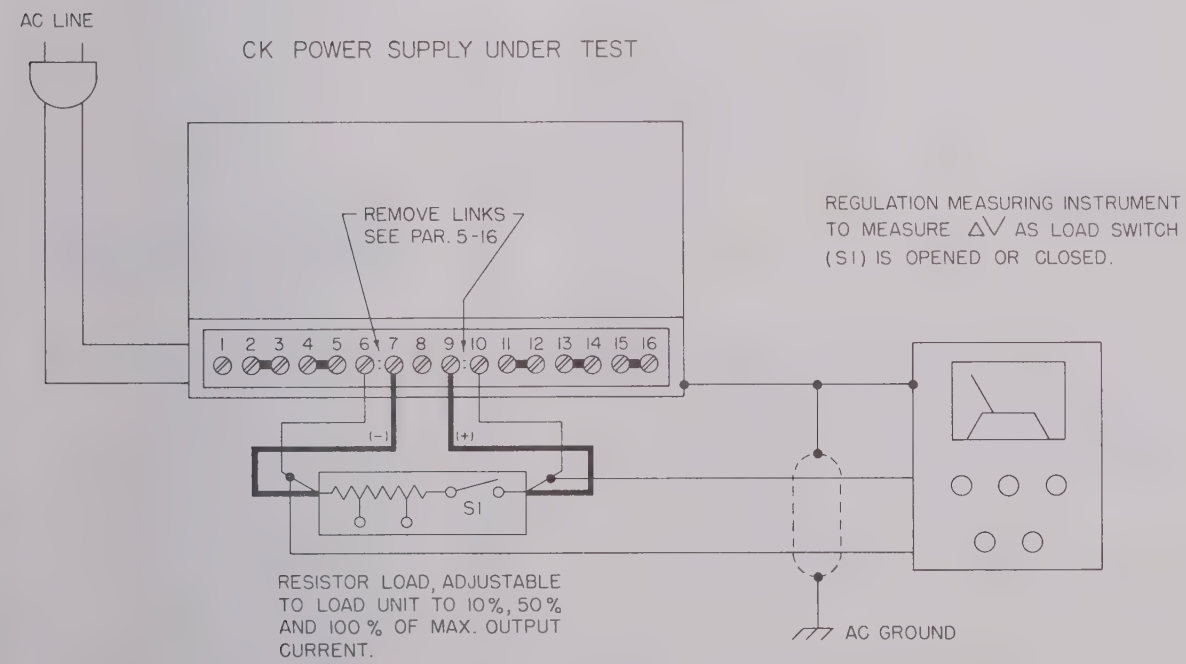

AC LINE
CK POWER SUPPLY UNDER TEST
REMOVE LINKS SEE PAR. 5-16
REGULATION MEASURING INSTRUMENT TO MEASURE ΔV AS LOAD SWITCH (S1) IS OPENED OR CLOSED.
1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16
(-)
(+)
S1
AC GROUND
RESISTOR LOAD, ADJUSTABLE TO LOAD UNIT TO 10%, 50% AND 100% OF MAX. OUTPUT CURRENT.

FIG. 5-4 MEASURING LOAD REGULATION (VOLTAGE MODE) WITH REMOTE ERROR SENSING.

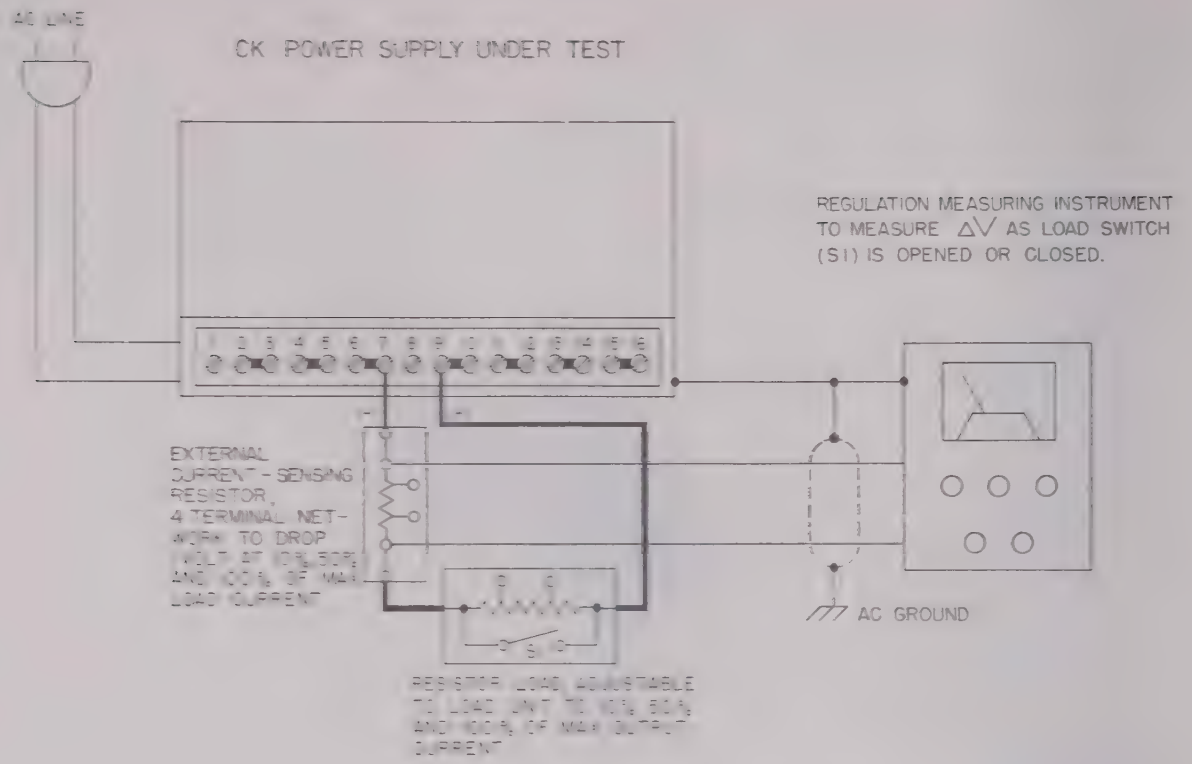


FIG 5-5 MEASURING LOAD REGULATION IN THE CURRENT MODE

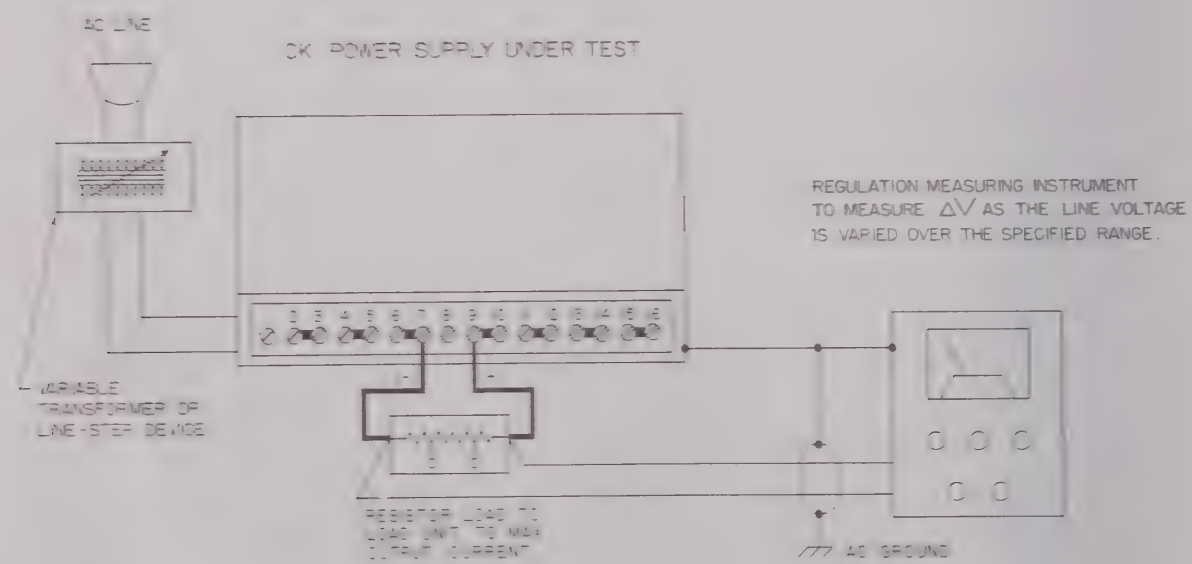


FIG 5-6 MEASURING LINE REGULATION

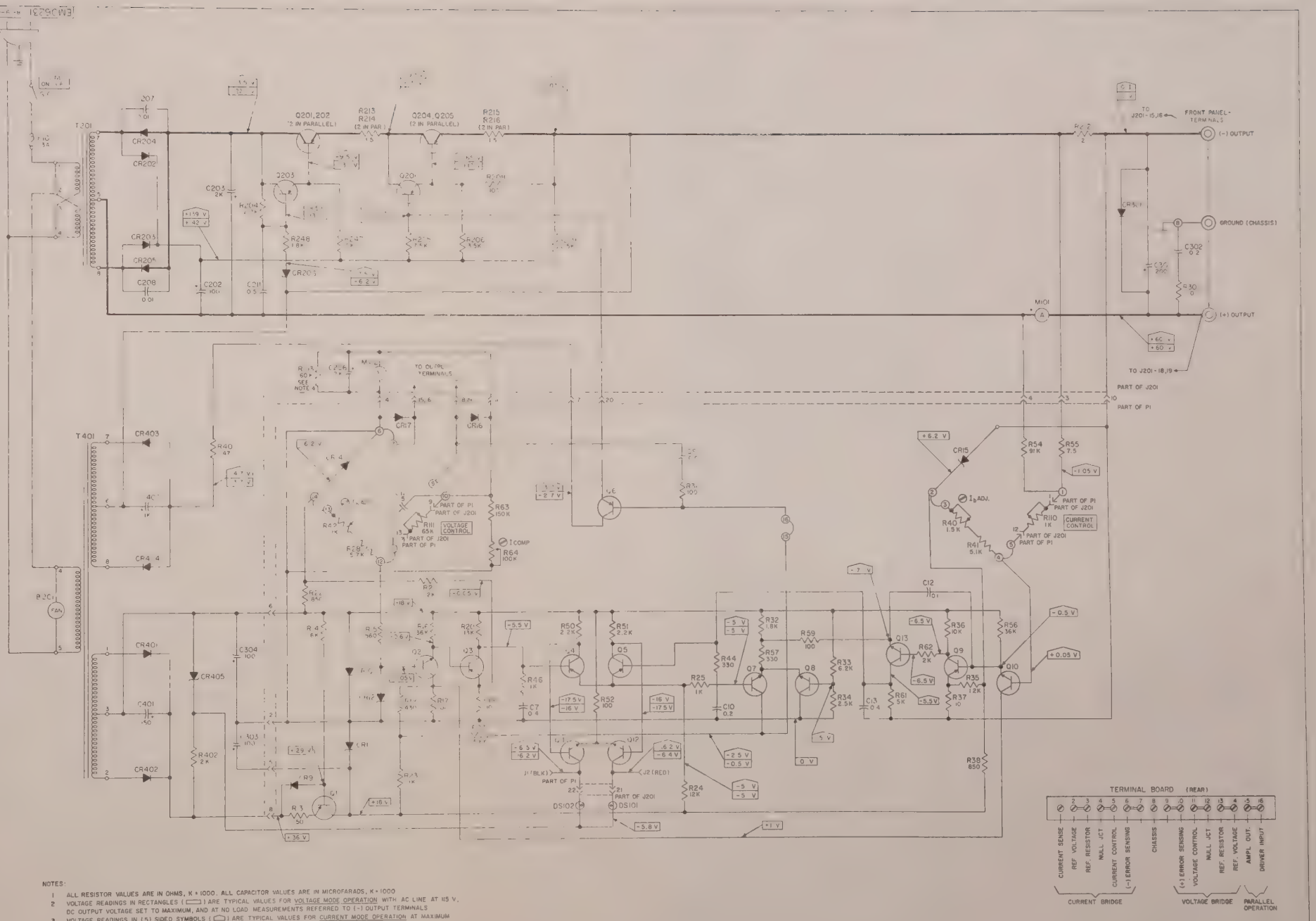

NOTES:
1 ALL RESISTOR VALUES ARE IN OHMS, K = 1000. ALL CAPACITOR VALUES ARE IN MICROFARADS, K = 1000
2 VOLTAGE READINGS IN RECTANGLES ( ) ARE TYPICAL VALUES FOR VOLTAGE MODE OPERATION WITH AC LINE AT 115 V. DC OUTPUT VOLTAGE SET TO MAXIMUM, AND AT NO LOAD. MEASUREMENTS REFERRED TO (-) OUTPUT TERMINALS
3. VOLTAGE READINGS IN (5) SIDED SYMBOLS ( ) ARE TYPICAL VALUES FOR CURRENT MODE OPERATION AT MAXIMUM OUTPUT VOLTAGE AND CURRENT. MEASUREMENTS REFERRED TO (-) OUTPUT TERMINALS
4. M101, M102 ARE USED IN METERED UNITS ONLY. R103 IS USED IN UNMETERED UNITS ONLY
5. VOLTAGE READINGS WHICH APPLY TO NOTES 2 & 3 ARE TYPICAL AND SUBJECT TO COMPONENT TOLERANCES
6 ORDER REPLACEMENT PARTS BY KEPCO PART NO. SEE PARTS LIST
TERMINAL BOARD (REAR)
CURRENT SENSE
REF. VOLTAGE
REF. RESISTOR
NULL JCT
CURRENT CONTROL
(-) ERROR SENSING
CHASSIS
(+) ERROR SENSING
VOLTAGE CONTROL
NULL JCT
REF. RESISTOR
REF. VOLTAGE
AMPL. OUT
DRIVER INPUT
CURRENT BRIDGE
VOLTAGE BRIDGE
PARALLEL OPERATION

FIG. 5-7 MAIN SCHEMATIC, CK 60-0.5

kepco inc. ® REPLACEMENT PARTS LIST

AMPLIFIER BOARD, ASSEMBLY PCB#1 MODEL CK 60-0.5(M) Code 8-1966

SCHEMATIC NO.	QTY.	DESCRIPTION	MFRS. NAME & PART NO. (See Note)	KEPCO PART NO.
C7,13	2	Capacitor,Mylar,Pigtail 0.4 µF, 200 V, 10%	TRW Type X663F	117-0128
C9	1	Capacitor,Mylar,Pigtail 0.01 µF, 200 V, 10%	Sprague 192P10302	117-0353
C10	1	Capacitor,Mylar,Pigtail 0.2 µF, 200 V, 10%	TRW Type X663F	117-0236
C11	1	Capacitor,Mylar,Pigtail 0.5 µF, 200 V, 10%	Wesco Type 32MM	117-0575
C12	1	Capacitor,Mylar,Pigtail 0.1 µF, 200 V, 10%	TRW Type X663F	117-0363
CR9,12	2	Zener Diode	Transitron SV125	121-0028
CR10,11	2	Zener Diode	Motorola 1N3026B	121-0036
CR14,15	2	Zener Diode	International Rect. 1N821	121-0041
CR16,17	2	Rectifier,Silicon,Pigtail	Solitron 124-0178	124-0178
Q1	1	Transistor,PNP	Delco 2N174	119-0016
Q2,7,8, 10,11,12,13	7	Transistor,Silicon,NPN	General Electric 2N338	119-0054
Q3,4,5,6,9	5	Transistor,Silicon,PNP	Hughes 2N1138A	119-0055
R13	1	Resistor,Fixed,Molded 150 ohm, 3 W, 5%	Hardwick Hindle 720	115-0481
R14	1	Resistor,Fixed,Power,Axial 6 K ohm, 3 W, 5%	Tepro TS3C	115-1155
R15	1	Resistor,Fixed,Molded 560 ohm, 1/2 W, 10%	Allen Bradley EB5611	115-0451
R16,56	2	Resistor,Fixed,Precision,WW 36 K ohm, 2 W, 5%	Tepro TS2C	115-1313
R17,31 52,59	4	Resistor,Fixed,Molded 100 ohm, 1/2 W, 10%	Allen Bradley EB1011	115-0626
R18	1	Resistor,Fixed,Molded 430 ohm, 1/2 W, 5%	Allen Bradley EB4315	115-0581
R19,37	2	Resistor,Fixed,Precision,WW 10 ohm, 3 W, 5%	Ward Leonard 3X10	115-0421
R20	1	Resistor,Fixed,Power,Axial,WW 13 K ohm, 1 W, 5%	Tepro TS1W	115-1309
R21,35	2	Resistor,Fixed,Precision,WW 1.2 K ohm, 1 W, 5%	Tepro TS1W	115-1306
R22,38	2	Resistor,Fixed,Precision,WW 850 ohm, 1 W, 1%	Tepro TS1W	115-1311

REPLACEMENT PARTS MAY BE ORDERED FROM KEPCO, INC. ORDERS SHOULD INCLUDE KEPCO PART NUMBER AND DESCRIPTION.

PLEASE NOTE: THE MANUFACTURER'S NAME AND PART NUMBER LISTED FOR EACH ITEM ON REPLACEMENT PARTS LISTS, REPRESENTS AT LEAST ONE SOURCE FOR THAT ITEM AND IS LISTED SOLELY FOR THE CONVENIENCE OF KEPCO EQUIPMENT OWNERS IN OBTAINING REPLACEMENT PARTS LOCALLY. WE RESERVE THE RIGHT TO USE EQUIVALENT ITEMS FROM ALTERNATE SOURCES. KEPCO, INC.

kepco inc.®

REPLACEMENT PARTS LIST

AMPLIFIER BOARD, ASSEMBLY PCB#1 MODEL CK 60-0.5(M) Code 4-1565

SCHEMATIC NO.	QTY.	DESCRIPTION	MFRS. NAME & PART NO. (See Note)	KEPCO PART NO.
R23	1	Resistor,Fixed,Molded 1.1 K ohm, 1/2 W, 5%	Allen Bradley EB1125	115-0448
R24	1	Resistor,Fixed,Molded 12 K ohm, 1/2 W, 10%	Allen Bradley EB1231	115-1168
R25	1	Resistor,Fixed,Molded 1 K ohm, 1/2 W, 5%	Allen Bradley EB1021	115-0547
R27	1	Resistor,Fixed,Molded 5.6 K ohm, 1/2 W, 10%	Allen Bradley EB5621	115-1201
R28	1	Resistor,Fixed,Precision,WW 5.7 K ohm, 1 W, 1%	Tepro TS1W	115-1301
R32	1	Resistor,Fixed,Molded 1.8 K ohm, 1/2 W, 10%	Allen Bradley EB1821	115-0473
R33	1	Resistor,Fixed,Precision,WW 6.2 K ohm, 1 W, 5%	Tepro TS1W	115-1335
R34	1	Resistor,Fixed,Precision,WW 2.5 K ohm, 1 W, 5%	Tepro TS1W	115-1307
R36	1	Resistor,Fixed,Power,Axial 10 K ohm, 3 W, 5%	Sprague 151E-10K	115-0460
R40	1	Resistor,Variable 1.5 K ohm, 1/2 W, 10%	Bourns 3067P-1-152	115-1535
R41	1	Resistor,Fixed,Precision 5.1 K ohm, 1 W, 1%	Tepro Electric TS1W	115-1572
R42	1	Resistor,Variable 1 K ohm, 1/2 W, 5%	Bourns 7067-S-1-102	115-0739
R44,57	2	Resistor,Fixed,Molded 330 ohm, 1/2 W, 10%	Allen Bradley EB3311	115-0804
R46	1	Resistor,Fixed,Molded 1 K ohm, 1/2 W, 10%	Allen Bradley EB1021	115-0547
R50,51	2	Resistor,Fixed,Molded 2.2 K ohm, 1/2 W, 10%	Allen Bradley EB2221	115-0466
R54	1	Resistor,Fixed,Molded,Glass 91 K ohm, 1/2 W, 5%	Corning Glass C20	115-1440
R55	1	Resistor,Fixed,Precision,WW 7.5 ohm, 1 W, 1%	Tepro TS1W	115-1377
R61	1	Resistor,Fixed,Power,Axial,WW 5 K ohm, 3 W, 5%	Hardwick Hindle 9/16 GA 5000 LTC	115-1094
R62	1	Resistor,Fixed,Molded 2 K ohm, 1/2 W, 5%	Allen Bradley EB2025	115-0520
R63	1	Resistor,Fixed,Molded,Glass 150 K ohm, 1/2 W, 5%	Corning Glass C20	115-1483
R64	1	Resistor,Variable 100 K ohm, 1/4 W, 20%	Allen Bradley FR104M	115-1500

REPLACEMENT PARTS MAY BE ORDERED FROM KEPCO, INC. ORDERS SHOULD INCLUDE KEPCO PART NUMBER AND DESCRIPTION.

PLEASE NOTE: THE MANUFACTURER'S NAME AND PART NUMBER LISTED FOR EACH ITEM ON REPLACEMENT PARTS LISTS, REPRESENTS AT LEAST ONE SOURCE FOR THAT ITEM AND IS LISTED SOLELY FOR THE CONVENIENCE OF KEPCO EQUIPMENT OWNERS IN OBTAINING REPLACEMENT PARTS LOCALLY. WE RESERVE THE RIGHT TO USE EQUIVALENT ITEMS FROM ALTERNATE SOURCES. KEPCO, INC.

REPLACEMENT PARTS LIST

POWER SUPPLY, MODEL CK 60-0.5 (M) Code 7-1665

SCHEMATIC NO.	QTY.	DESCRIPTION	MFRS. NAME & PART NO. (See Note)	KEPCO PART NO.
FRONT PANEL ASSEMBLY, INCLUDES THE FOLLOWING:				
DS101,102	2	Pilot Light Assembly	Drake Mfg. 7-503	152-0071
F101	1	Fuse,Slo Blo 3 A, 125 V	Bussman MDX-3	141-0028
*M101	1	Meter, Amp. 0-500 ma, DC	General Electric 8DW91A355BK2	135-0201
*M102	1	Meter, Volt 0-50 V, DC	General Electric 8DW91V202AR2	135-0149
**R103	1	Resistor,Fixed,Precision 60 K ohm, 5 W, 3%	Tepro TS-5W	115-1530
R110	1	Resistor,Variable,10-Turn 1 K ohm, 3 W, 3%	Spectrol 510 series	115-1304
R111	1	Resistor,Variable,10-Turn 65 K ohm, 3 W, 3%	Bourns 3500S	115-1325
S101	1	Switch,Toggle,SPST 15 A, 125 V	Carling AA252-63XKEP2	127-0107

*Metered Models Only.
**Unmetered Models Only.

REPLACEMENT PARTS MAY BE ORDERED FROM KEPCO, INC. ORDERS SHOULD INCLUDE KEPCO PART NUMBER AND DESCRIPTION.

PLEASE NOTE: THE MANUFACTURER'S NAME AND PART NUMBER LISTED FOR EACH ITEM ON REPLACEMENT PARTS LISTS, REPRESENTS AT LEAST ONE SOURCE FOR THAT ITEM AND IS LISTED SOLELY FOR THE CONVENIENCE OF KEPCO EQUIPMENT OWNERS IN OBTAINING REPLACEMENT PARTS LOCALLY. WE RESERVE THE RIGHT TO USE EQUIVALENT ITEMS FROM ALTERNATE SOURCES. KEPCO, INC.

REPLACEMENT PARTS LIST

POWER SUPPLY MODEL CK 60-0.5(M) Code 7-1665

SCHEMATIC NO.	QTY.	DESCRIPTION	MFRS. NAME & PART NO. (See Note)	KEPCO PART NO.
MAIN CHASSIS ASSEMBLY, INCLUDES THE FOLLOWING:				
B201	1	Motor	Barber Colman DYAF761-1	148-0007
C202	1	Capacitor, Electrolytic, Pigtail 100 µF, 150 V	Industrial Cond. 10B916RM	117-0140
C203, 206	2	Capacitor, Electrolytic, Can 2000 µF, 125 V	General Electric 43F3267CA6	117-0391
C207, 208	2	Capacitor, Mylar 0.01 µF, 200 V, 10%	Sprague 192P10302	117-0353
C211	1	Capacitor, Mylar 0.5 µF, 200 V, 10%	TRW Type X663F	117-0123
CR202, 203, 204, 205	4	Rectifier, Silicon, Pigtail	Semicon SM140/S	124-0028
CR206	1	Zener Diode	Transitron SV125	121-0028
Q201, 202, 203, 204, 205, 206	6	Transistor, PNP	Delco 2N174	119-0016
R204	1	Resistor, Fixed, Molded 2.2 K ohm, 2 W, 10%	Allen Bradley HB2221	115-0491
R205	1	Resistor, Fixed, Power, Strip 7.5 K ohm, 20 W, 5%	Hardwick Hindle 2BRS-56-7500	115-1125
R206	1	Resistor, Fixed, Power, Strip 3.5 K ohm, 20 W, 5%	Hardwick Hindle 2BRS-56	115-1378
R208	1	Resistor, Fixed, Molded 100 ohm, 1/2 W, 10%	Allen Bradley EB1011	115-0626
R209	1	Resistor, Fixed, Power, Strip 2.5 K ohm, 20 W, 5%	Ward Leonard 20S2500	115-0822
R212	1	Resistor, Precision 2.0 ohm, 50 W, 1%	Tepro TM-50W	115-1389
R213, 214 215, 216	4	Resistor, Fixed, Power, Axial 1.5 ohm, 3 W, 5%	Ward Leonard 3X1.5	115-0517
R247	1	Resistor, Fixed, Power, Axial 5 K ohm, 5 W, 5%	Ward Leonard 5X5000	115-0232
R248	1	Resistor, Fixed, Molded 1.8 K ohm, 2 W, 10%	Allen Bradley HB1821	115-0139
T201	1	Transformer	Kepco Magnetics	100-1371

REPLACEMENT PARTS MAY BE ORDERED FROM KEPCO, INC. ORDERS SHOULD INCLUDE KEPCO PART NUMBER AND DESCRIPTION.

PLEASE NOTE: THE MANUFACTURER'S NAME AND PART NUMBER LISTED FOR EACH ITEM ON REPLACEMENT PARTS LISTS, REPRESENTS AT LEAST ONE SOURCE FOR THAT ITEM AND IS LISTED SOLELY FOR THE CONVENIENCE OF KEPCO EQUIPMENT OWNERS IN OBTAINING REPLACEMENT PARTS LOCALLY. WE RESERVE THE RIGHT TO USE EQUIVALENT ITEMS FROM ALTERNATE SOURCES. KEPCO, INC.

kepco inc. ® REPLACEMENT PARTS LIST

POWER SUPPLY, MODEL CK 60-0.5(M) Code 7-1665

SCHEMATIC NO.	QTY.	DESCRIPTION	MFRS. NAME & PART NO. (See Note)	KEPCO PART NO.
AUXILIARY BOARD (RB1), INCLUDES THE FOLLOWING:				
C301	1	Capacitor, Electrolytic, Pigtail 200 µF, 100 V, 10%	General Electric 43F2536-AA1	117-0358
C302	1	Capacitor, Mylar 0.25 µF, 600 V, 20%	Good All 620S20406W	117-0200
C303, 304	2	Capacitor, Electrolytic, Pigtail 100 µF, 25 V	Sprague TE-1211	117-0289
CR301	1	Rectifier, Germanium, Pigtail	General Electric 1N93	122-0029
R301	1	Resistor, Fixed, Molded 10 ohm, 1/2 W, 10%	Allen Bradley EB1001	115-0502
AUXILIARY BOARD (RB2), INCLUDES THE FOLLOWING:				
C401	1	Capacitor, Electrolytic, Pigtail 150 µF, 75 V	General Electric 43F7147-AA1	117-0388
C402	1	Capacitor, Electrolytic, Pigtail 1 K µF, 6 V	Industrial Cond. 1B1382-RM	117-0346
CR401, 402	2	Rectifier, Silicon, Pigtail	Semicon SM-140/S	124-0028
CR403, 404	2	Rectifier, Silicon, Pigtail	Semicon SM-110	124-0133
CR405	1	Zener Diode	Hoffman HZ(1)R12	121-0012
R401	1	Resistor, Fixed, Molded 47 ohm, 1/2 W, 10%	Allen Bradley EB4701	115-0718
R402	1	Resistor, Fixed, Power, Axial 2 K ohm, 5 W, 5%	Ward Leonard 5X2000	115-0568
T401	1	Transformer	Kepco Magnetics	100-1343

REPLACEMENT PARTS MAY BE ORDERED FROM KEPCO, INC. ORDERS SHOULD INCLUDE KEPCO PART NUMBER AND DESCRIPTION.

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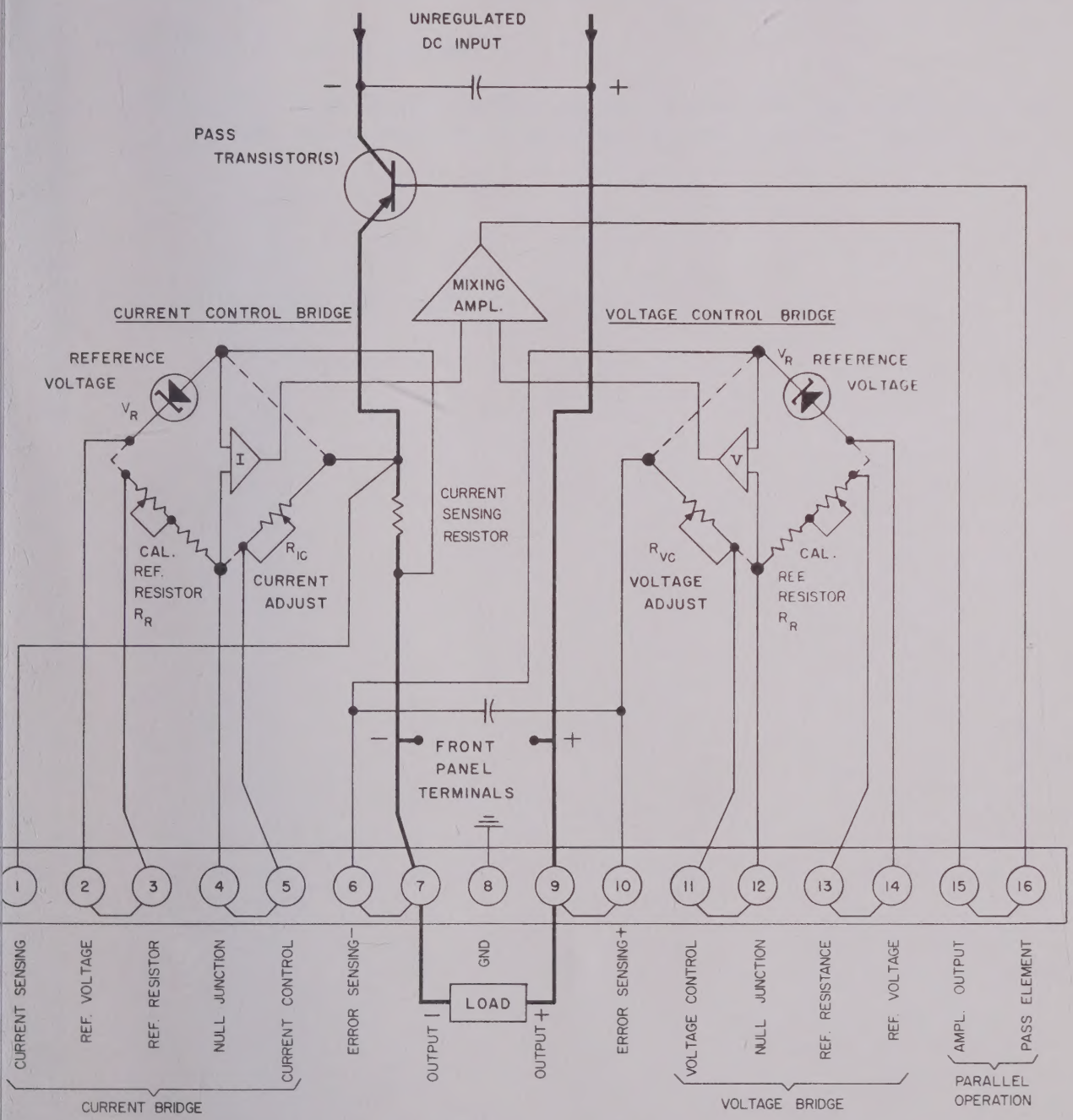
SIMPLIFIED DIAGRAM OF MODEL CK AUTO-CROSSOVER POWER SUPPLY

WITH REAR TERMINAL CONNECTION DETAIL



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INSTRUCTION MANUAL CORRECTION

Please note the following corrections to the Manual Material as indicated:

Parts List & Schematic Diagram:

1. Change R37 Resistor, Fixed, Power, Axial 10 ohm, 3 W, 5% Kepco #115-0421 to
   R37 Resistor, Fixed, Power, Axial 15 ohm, 3 W, 5% Kepco #115-1650.

CK 60-0.5(M)/7-1267/r12 C1710

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